THE "COMPLETE ENGINEER" SERIES • VOLUME 2

AIRCRAFT PRODUCTION

A PRACTICAL SURVEY OF MATERIALS AND PROCESSES USED IN THE CONSTRUCTION OF MODERN AIRCRAFT. INTENDED FOR ALL ENGAGED IN AIRCRAFT FACTORIES AND ASSEMBLY SHOPS

Prepared by a Staff of Technical Experts under the direction of

E. MOLLOY

WITH EIGHTY-ONE ILLUSTRATION

GEORGE NEWNES LIMITED
TOWER HOUSE, SOUTHAMPTON STREET, STRAND
LONDON, W.C.2
1941

THE "COMPLETE ENGINEER" SERIES

VOL.

1 INTRODUCTION TO WORKS PRACTICE

2 AIRCRAFT PRODUCTION

3 DIESEL ENGINE OPERATION

4 TEST ENGINEERS' HANDBOOK

5 PUMPS AND PUMPING

6 STEAM FOR INDUSTRIAL PROCESSING

7 SHEET-METAL WORK

8 DRILLING AND GRINDING

9 MILLING PRACTICE

10 PIPES AND VALVES

11 FITTING PRACTICE

12 MECHANICAL POWER TRANSMISSION

13 STEAM ENGINES AND BOILERS

14 LATHEWORK

15 PATTERN-MAKING AND FOUNDRYWORK

16 HYDRAULIC MACHINERY

PRINTED IN GREAT BRITAIN BY HAZELL, WATSON & VINEY, LTD., LONDON AND AYLESBURY

PREFACE

MANY engineers who are to-day engaged on the vital work of aircraft production have been drafted into the industry from other branches of engineering. In aircraft factories these engineers have to work materials such as aluminium alloys and magnesium alloys and special steels which are quite different from anything they have encountered in their general engineering work.

The processes of manufacture, too, although they are based upon standard engineering practice, differ considerably in detail from those which have formed the basis of standard engineering production work.

The present book presents an up-to-date survey of the materials and processes used in this comparatively new sphere of engineering activity.

The information has been classified under seven headings: namely, Materials, Work Methods, Methods of Joining Components, Assembly, Wooden Aircraft, Aero Engines, and Airscrews. The book concludes with a chapter outlining the processes involved in the production of a sleeve-valve aero engine.

Without entering too deeply into the detailed manufacturing sequence, as applied to any particular aircraft, this book shows clearly the relation which each process bears to the production of the completed aeroplane.

It is hoped that the presentation of this material, in a form convenient for ready reference, will prove to be of real utility to those engineers who are devoting their skill and energies to the highly important task of aircraft production.

E. M.

CONTENTS

AIRCRAFT PRODUCTION

Chapter I

MATERIALS USED IN AIRCRAFT CONSTRUCTION

AIRCRAFT engineering is a very wide subject and includes research, design, and production. In the following pages it is proposed to deal with the practical side of the subject, namely, the actual construction or manufacture of aeroplanes.

This can be split into two sections : (*a*) airframe production and (*b*) engine production ; both of which are entirely different.

As the name implies, the airframe is the framework or body of the machine, and includes the wings, fuselage, elevators, rudders, etc. The names of the various units comprising the airframe are given in Fig. 2. Two main types exist, one consisting of a wooden framework covered with fabric, and the other of a metal framework covered with a thin metal skin.

Although a large number of wooden aircraft are still being built, the majority of machines are now of the all-metal type. This is particularly so in the case of military aircraft and large air-liners. For this reason the production of this type will be dealt with first, in the following sequence : (1) materials, (2) workshop production process, (3) design and manufacture of the various units which make up an aeroplane.

With the exception of a few castings, forgings, and fittings such as windows, engine mountings, and wheels, most modern all-metal airframes are almost wholly built from light-alloy materials. However, an all-steel plane has recently been successfully built and flown in this country, and it is quite probable that steel may play a more important part in the future. At present, its use is confined to a certain amount of fuselage work, small forged and sheet-metal fittings, spars, and other wing parts. Stainless steel is often employed for hulls and seaplane fittings.

Materials

Every new material used for aircraft work is subjected to very stringent tests before permission can be obtained for its general use. After approval has been given by the Air Ministry, the specification of

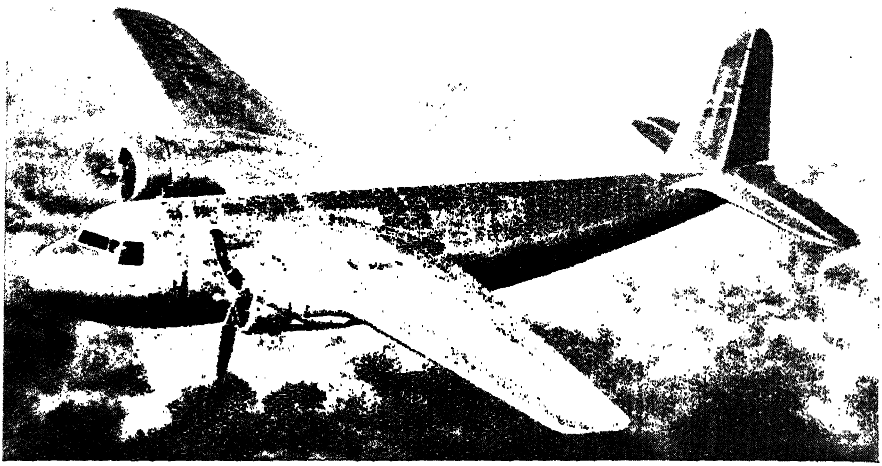


Fig. 1.—A TYPICAL MODERN ALL-METAL AIR-LINER, THE DOUGLAS DC–5 TWIN-ENGINE MACHINE

This aeroplane can carry 16 passengers, and has a span and length of 78 feet and 60 feet. The gross weight is just over 8 tons. (*Douglas Aircraft Co. Inc.*)

the material is listed under a number, known as the D.T.D. number. Processes, such as metal spraying, are also defined by D.T.D. numbers. In the case of light-alloy sheet metal, special distinctive coloured markings are painted on the surface of each sheet to enable instant indentification. This is very important, as certain alloys require special treatment in order to retain their properties, and weak parts could be easily produced in an airframe by using components not made from the correct material. These markings are specified by the Air Ministry and standardised throughout the country. It is very difficult to keep up-to-date with aircraft materials, as new alloys are constantly being produced. The following data, however, will provide a guide to those in general use.

ALUMINIUM ALLOYS

Duralumin

One of the most extensively used light-alloy materials for aircraft work is duralumin, which is available in such forms as sheet, rod, tube, extruded section, rivets, and stock for forging.

Chemical Composition (" B " Grade) :

Copper : 3·5 to 4·5 per cent.
Manganese : 0·4 to 0·7 per cent.
Magnesium : 0·4 to 0·7 per cent.
Aluminium : About 94·5 per cent.

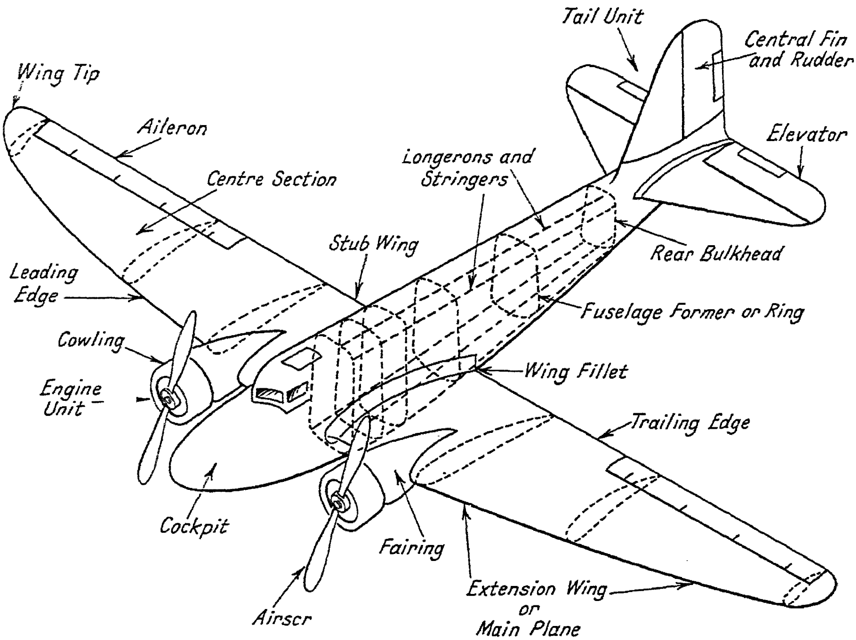


Fig. 2.—The names of the various units comprising an airframe

Physical Properties ("B" Grade):

Specific gravity: Approximately 2·8.

Specific heat: 0·214 (water = 1).

Thermal conductivity: 31 (silver = 100).

Electrical conductivity: Normalised 33 to 35 per cent. (copper = 100). Annealed 39 to 41 per cent. (copper = 100).

Co-efficient of linear expansion: 0·00001255 per ° Fahr.; 0·0000226 per ° Cent.

Young modulus of elasticity (E): 4,500 tons per square inch.

Melting range: 560° to 650° Cent.

Annealing range: 360° to 400° Cent.

Heat treatment or normalising temperature: 480° Cent.; 10° C.

Forging temperature: 400° to 470° Cent.

Mechanical Properties:

Brinell hardness: Annealed 60 (approx.); normalised 90 to 115.

Fatigue range: 9·5 tons per square inch.

Izod impact value: About 15 ft. lb.

For special purposes other grades (A.M. and H.) are supplied. These vary somewhat in composition, according to the purpose for which they are intended.

Heat Treatment of Duralumin

This material is usually supplied to the user in its final heat-treated condition, known as "normal." When in this condition duralumin is too hard to allow the carrying out of such shaping operations as spinning, bending, pressing, and special heat treatment is necessary before use. If the sheet is raised to a temperature of 480° C. and then suddenly cooled, it becomes softer and can be easily worked. The temperature must be closely controlled and not allowed to vary by more than ± 10° C.

However, the effect of this treatment, known as "normalising," is not permanent, and after a few hours the metal gradually returns to its original unworkable condition, this hardening action being known as "ageing." All work should be carried out within two hours of cooling. If the operations are likely to require more than this period, it is necessary to reduce the material to a semi-permanent soft condition by an "annealing" process.

For this the duralumin is heated to a temperature of 360° C. and then cooled in air or water. At no time should the temperature exceed 400° C. After completion of the work-operations, the "normalising" process mentioned above is applied to return the material to its original hardness. Duralumin must never, under any circumstances, be heated above 490° C.

HEAT TREATMENT OF WROUGHT ALLOYS

Alloy	*Solution Heat Treatment*	*Quenching Medium*	*Precipitation Heat Treatment*
Duralumin . . .	Heat in salt bath or muffle furnace at 485°–495° C.	Water or oil	Ages at room temperature in 4 days, yielding maximum properties.
"Duralumin—H" . .	Raise to between 510° and 520° C.	Water	Reheat at 155°–175° C. for 12 to 14 hours.
Hiduminium RR56 . .	Soak at 525°–535° C. for 2 hours.	Water at 70°–100° C.	Reheat at 165°–175° C. for 10 to 20 hours and quench in water.
Y-Alloy	Soak at 500°–520° C. for 6 hours.	Boiling water	Properties reached after 5 days at room temperature or after 1 to 2 hours in boiling water.

(*Courtesy of British Aluminium Co., Ltd.*)

In the modern aircraft factory a separate shop is set aside for this work, being usually equipped with a series of large baths, arranged side by side and fed from a light overhead crane. Heating is usually done in gas-fired "salt baths," although some firms employ electric muffle furnaces, especially for castings and forgings. The temperature must be very closely controlled, to ensure that the original strength is returned

to the material after completion of the treatment. Adjacent to each salt bath is a tank of similar size containing water, into which the heated work is quickly immersed for cooling. The work is held in steel racks, or baskets, which can be lifted bodily from one bath to another, and in both baths it is very important that the work should be completely immersed.

Extensive use is now being made of refrigerators to minimise the inconveniences due to heat treatment.

In addition to duralumin, it is also necessary to heat treat other types of aluminium alloys, such as are used for castings and forgings. In this case, however, the treatment is made with the sole object of giving strength and other physical properties to the work, and not because of softening made necessary for some previous operation. (See table on previous page.)

During "ageing," dimensional changes are liable to occur with certain alloys, and thus special care must be taken with work which is machined to accurate dimensions. With such alloys it is customary to rough-machine the work while the metal is in its original condition, and then give the necessary heat treatment, following this with the final machining operation.

Machining Duralumin

The following machining notes are given by the manufacturers, James Booth & Co. (1915), Ltd.

Duralumin in the normalised or fully heat-treated condition is a "free-turning" material, and takes a fine vee-thread quite satisfactorily. Annealed bars or untreated forgings do not machine quite so easily, the material in either of these forms being of a more "luggy" nature than the heat-treated alloy.

As a general guide, it may be taken that machining speeds and feeds are of the orders usually employed for brass, whilst the appropriate cutting tools most nearly resemble those used for wood-turning, or those employed for the machining of copper.

The following approximate figures should be useful for general purposes, although modifications can be made when repetition work in large quantities is being handled.

Type of Operation	*Cutting Speed in ft. per min.*	*Depth of Cut in ins.*	*Traverse or Feed in ins. per rev.*
Roughing .	100/200	$\frac{1}{16}$ to $\frac{3}{32}$	$\frac{1}{32}$
Finishing .	200/500	$\frac{1}{64}$ to $\frac{1}{32}$	$\frac{1}{64}$

The roughing cuts are run dry and the finishing cuts are usually lubricated. The chosen lubricant may be any reliable cutting compound, preferably those containing the smallest proportion of alkaline constituents. Alternatively, a mixture of paraffin and lard oil may be employed

in proportions that are varied according to the nature of the work, and to the workshop temperature. This alternative lubricant is recommended for its all-round utility and effectiveness, whilst it also has the advantage that the turnings are not affected by it in any detrimental way. Some cutting compounds set up oxidation of the turnings so rapidly as to render them quite valueless in a very short time.

Cutting tools should be of high-speed steel, or a good-quality tool steel, and should be kept quite sharp.

A round-edge tool is sometimes used for finishing, as it retains its cutting edge better than the bevelled type. A side rake of from 5° to 10° is usually found to give satisfactory results. Similar tools will generally be found suitable for planing, shaping, or slotting.

Drills should have as much clearance as possible, and should always be lubricated. Some difficulty may be experienced in removing the chips when drilling deep holes, and the drill may need to be withdrawn at intervals to clear itself. For milling, cutters with inserted teeth are to be preferred.

They should always be kept very sharp, and if the precautions indicated for turning are observed, no difficulties should be experienced.

Anodising

Aluminium alloys are liable to corrosion in a similar manner to ferrous metals, particularly when subjected to sea air or salt water. Naturally, this corrosion weakens the material, and thus it is very important to prevent its formation. Paint is unsuitable, as it cannot be successfully "keyed" to the surface and, after a very short time, flakes off under the effect of vibration and other causes. The recognised protective treatment for aluminium and its alloys is "anodising," an electrolytic process requiring very similar plant to that used for electroplating.

When exposed to the atmosphere the surface of aluminium becomes covered with a very thin film of colourless oxide, which protects the surface against the effects of corrosion. The protective qualities of this film are so excellent that it has been adopted as the recognised anti-corrosion treatment. Anodising is a process for artificially producing this film and, although much thicker than the natural film, the anodic coating is less than one-thousandth of an inch in thickness. There are three anodising processes, these differing mainly in the type of electrolyte or solution used, and each giving a slightly different surface colour. The earliest process was discovered by Bengough, after whom it is named. This employs a solution of approximately 3 per cent. chromic acid in distilled water and, on pure aluminium, gives a light grey opaque film. A solution of sulphuric acid is used for the second process, and this gives a more transparent film than the Bengough process. The third process employs a 3 per cent. solution of oxalic acid in water, which gives a slightly yellowish tinge to the film.

The Process

Anodic treatment consists of suspending the work in a steel bath containing one of the solutions previously mentioned. Along the top are three brass tubes. The work is hung from the centre tube by an aluminium wire or clip, and forms the anode. From the other two tubes are suspended graphite plates, these being the cathode. Coils, through which either steam or cold water can be passed, are arranged at the bottom of the tank to control the temperature. Provision is also made to agitate the solution to prevent the formation of bubbles on the work surface.

Prior to immersion it is very important to make sure that the work is absolutely clean, by washing it in hot water. If dirt or paint adheres to the surface, it must be removed with the aid of petrol or by other means. For the Bengough process the electrolyte should be at a temperature of 40° C. before immersion of the work. The current is raised at a uniform rate from zero to 40 volts during the first fifteen minutes, and maintained at this figure for a further thirty-five minutes. During the next five minutes the voltage is raised to 50 volts, and remains at this for a further five minutes. Following a wash in hot water, the work is dried by a sawdust bath, hot air, or by storage under ordinary atmospheric conditions.

It will be seen that, due to the changes in voltage during the process, work cannot be added or taken away until the one-hour treatment is completed. This is one of the disadvantages of this particular process. With the other two processes, the voltage is kept at a constant figure, thus enabling work to be added or withdrawn as desired. Parts riveted or bolted together cannot be successfully anodised, and thus the work must be treated before assembly.

Alclad

Another sheet material widely used in aircraft construction is Alclad, which is of comparatively recent introduction. Both sides of the sheet are provided with a covering of pure aluminium, a feature rendering it practically immune from salt-water corrosion. Consequently, this material is very suitable for use on flying-boat hulls and other positions subjected to sea-air or water conditions.

Aldural

Another new material for aircraft purposes is "Aldural," regarding which the following information is given by the manufacturers, James Booth & Co., Ltd. Aldural has been produced in order to meet the demand for a material having the well-known characteristics of duralumin, but possessing, at the same time, a greater resistance to the more severe types of corrosive agents. Aldural can only be produced in the form of rolled metal, and consists of a coating of aluminium of the highest

degree of purity on each side of rolled duralumin. The coating on each face is about 5 per cent. of the thickness of the core.

This material has a strength but little inferior to that of duralumin, as would be expected from its construction, and the ductility is as good.

The working and heat treatment of Aldural demands the same technique as duralumin; but, in general, it will be found that, owing to the extremely ductile outer skin, forming operations can be carried out more easily than with the uncoated alloy. If it is desired to re-heattreat the alloy, great care should be exercised, especially with the thinner gauges. The time of exposure to the heat-treatment temperatures should be kept at a minimum. Undue soaking will tend to reduce the corrosion resistance of the coating.

Some idea of the resistance to corrosion offered by Aldural may be obtained from the following test figures, which show the effect upon the properties of unprotected Aldural of an intermittent salt spray in an accelerated corrosion test. It should be observed that such corrosion tests are much more severe in their effects than are the worst service conditions.

ALDURAL

Time of Exposure	0·1 *per cent. Proof Stress tons/square inch*	*Maximum Stress tons/square inch*	*Elongation per cent.*
0 days . .	17·20	25·30	18·0
50 ,, . .	17·00	25·10	17·0
100 ,, . .	17·10	25·10	18·0
150 ,, . .	16·90	25·20	17·5

MAGNESIUM

Magnesium is considerably lighter than aluminium, and consequently it is only natural that extensive use should also be made in aircraft construction of alloys of this metal. One of the outstanding magnesium alloys is Elektron, which has a specific gravity of approximately 1·82, and which can be used for sand casting, die casting, extrusion, forging, stamping, pressing, etc. Under normal atmospheric conditions the metal is practically corrosion-resistant, and for use under corrosive sea-water conditions a special surface treatment is available.

The following practical information is made available by the courtesy of F. A. Hughes & Co., Ltd.

Working of Sheet

Elektron sheets are supplied in the fully annealed condition and only a very limited amount of bending or shaping can be carried out in this condition at ordinary temperatures. The following figures will serve as a rough guide as to the minimum radii over which elektron sheets may be bent cold :

Alloy	Thickness S.W.G.	Thickness Mm.	Min. Bending Radii Inches	Min. Bending Radii Mm.
AZM	23	0·6	·125	3·0
,,	19	1·0	·25	7·0
,,	17	1·5	·437	11·0
,,	14	2·0	·75	20·0
AM.503	23	0·6	·104	2·5
,,	19	1·0	·25	7·0
,,	17	1·5	·437	11·0
,,	14	2·0	·75	20·0

All shaping calculated to exceed the severity of the bends given above must be carried out with the metal heated.

The optimum temperatures for hot working are:

For AM.503 . . . . From 270 to 330° C.
,, AZM . . . . ,, 270 ,, 300° C.

For sheets thinner than 14-gauge (2 mm.) the bending radius must not be less than twice the sheet thickness. For sheets thicker than 14-gauge, the minimum bending radius is from 1·5 to 1·8 times the sheet thickness. The slightest appearance of cracking at bends—even skin cracks—must be avoided, as these, when subject to alternating stress, are liable to lead to fracture.

When shaping or forming is carried out, as in the fabrication of cowlings or tank bodies, the best practice is to beat to shape over a wooden former. Use a blow-lamp, gas and air, or acetylene flame, to heat the sheet. A simple method of determining the correct temperature is to apply to the sheet a few drops of lubricating oil having a flash point of about 300° C. When the oil flashes, it will be found that the most suitable temperature has been attained for the deformation of the sheet. For heavy deformations, the best practice is to do a little at a time, annealing with the flame as required. The heat loss when using wooden formers is comparatively small and a considerable amount of work can be done in one heating.

If metal formers are used, then it is essential that these be brought up to the working temperature of the metal and, as far as possible, maintained at that temperature. In deep-drawing operations, it is desirable to raise the tools to a temperature higher than the working temperature, say, from 400° to 450° C., in order to avoid any chill to the metal as it comes into contact with the tools. In deep-drawing operations and, indeed, in all deformation processes on elektron, a slow rate of deformation is advisable. Welded joints properly made and hammered can be shaped just as readily as unwelded sheets.

Elektron Magnesium Alloys

Alloy Symbol	*D.T.D. Specn.*	*Supplied as*	*Aluminium Max.*	*Zinc Max.*	*Manganese Max.*	*Magnesum Approx.*	*Impurities Max.*
AZF .	59	Sand Castings	4·5	3·5	0·4	92	0·50
AZG .	59	Sand Castings	6·5	3·5	0·4	90	0·50
A.8 .	59	Sand Castings	8·0	1·5	0·4	90	0·50
AZ.31 .	136	Sand Castings Gravity Die Castings	3·25	1·25	0·4	94	1·50
VI .	136	Sand; Gravity Die; Pressure Die Castings	10·0	3·5	0·4	86	0·50
AM.503	140 142 118	Sand Castings Extrusions Sheets	0·20	0·20	2·50	96	0·50
AZM .	88A 127	Forgings Extrusions	10·0	1·5	1·0	87	1·5
Z.3 .	—	Sheets and Etching Plates	0·20	3·0	—	95	0·5
AZ.102	—	Extrusions	11.0	2·25	0·7	85	1·5
MG.5 .	—	Rivets and Wire	95·0	—	—	5	0·5
AZ.855	—	Forgings	8·5 to 9·0	0·2 to 0·6	0·1 to 0·3	91	0·5

Chemical analysis and uses of elektron alloys employed in aircraft work. (*Courtesy of F. A. Hughes & Co.*)

Riveting

Riveted joints can be made in elektron, using rivets of the alloy MG.5. The riveting is done cold. The sheer strength of these rivets can be taken as being 14 tons per square inch.

The most suitable diameter and spacing of rivets are given by the following formula:

$$D = 5\,S - 0{\cdot}015 \text{ (in inches).}$$

Where D = the diameter of the rivets and
S = the sheet thickness.

Rivet spacing:

$$T = 2{\cdot}6\,D - 0{\cdot}06 \text{ (in inches).}$$

Where T = the pitch of the rivets and
D = the diameter of the rivets.

MECHANICAL PROPERTIES

ELEKTRON AND OTHER METALS

Material	*D.T.D. Specn.*	*Condition*	*Proof stress, 0·1% (tons per sq. in.)*	*Ultimate stress (tons per sq. in.)*	*Elongation on 2 in. (%)*	*Brinell hardness*	*Specific gravity*	*Modulus of elasticity lb./sq. in.*
Elektron alloy AZ.91	D.T.D. 136A	As cast	4·5–5·5	8–10	1–3	55–65	1·81	$6·5 \times 10^6$
Elektron alloy A.8	D.T.D. 59A	As cast	4·5–5·5	9–11	3–5	50–60	1·81–1·83	$6·5 \times 10^6$
Elektron alloy AZM	D.T.D. 259	As extruded	9–12	18–22	16–12 ($4\sqrt{a}$ %)	55–60	1·81–1·83	$6·5 \times 10$
Elektron alloy AM.503	D.T.D. 118	Extruded or rolled	6–8	12–15	10–3 ($4\sqrt{a}$ %)	—	1·81–1·83	6×10^6
Aluminium alloy 3.L.5	—	As cast	Sand cast bar 4·75	9–10	2–4	58–65	3	$9·5 \times 10^6$
Aluminium alloy 4.L.11	—	As cast	Sand cast bar 3·75	7·5–8·5	1·5–2·5	50–55	2·9	$9·5 \times 10^6$
Aluminium-Silicon alloy L.33	—	As cast	Sand cast bar 4·0	10·5–11·5	5–10	45–55	2·6	9×10^6
Phosphor-bronze	—	Cast sand green	7–9	12–15	4–8	90	8·6	14×10^6
Cast steel	—	Annealed	14–15	28–32	10–12	150	7·8	30×10^6
Aluminium alloy 3.L.1 (Duralumin)	—	Extruded or forged	15	25	15	—	2·85	$10·5 \times 10^6$
Brass	—	Cast	3·5	13·5	39	50	8·6	9×10^6

(*Courtesy of F. A. Hughes & Co., Ltd.*)

Seams of simple or composite structures should be treated by the chromate pickling process before riveting, as a primary protection against corrosion, and again after riveting wherever possible.

In joining elektron to other materials such as steel, copper, brass, or wood, it should be insulated therefrom by strips of acid-free rubber or leather.

For attaching such materials as leather or aircraft fabric to elektron, cement-glue is the best adhesive, as this does not affect subsequent varnishing or impregnation of the material.

Elektron may be successfully welded by the oxy-acetylene flame, and, given the correct flux and welding rod, the achievement of good welds depends upon the manipulative skill of the welder. Skilled operators can acquire the technique, which is not more difficult, though requiring more precision, than the welding of aluminium. Welded elektron possesses high strength and durability.

Where the use of welded products in elektron is contemplated the alloy AM.503 should be specified, because it is the most suitable alloy for welding, whether in the form of sheets, tubes, sections, or machined parts. Generally, welded aircraft tanks and cowlings are made from AM.503.

The Alloy AZM is also weldable, though not so easily as AM.503. Very successful work has been done with this alloy in the construction of seats, luggage racks, and the secondary furnishings for aircraft in the popular tubular design. Such products have considerable strength and lightness.

For welding AM.503 use welding rod "AM.503," and for welding AZM welding rod "AZM" or "V.I." For sheet work, thin-gauge tubes, and sections, specify liquid flux.

Elektron flux is corrosive and must be scrupulously removed from finished welds by vigorous brushing in hot water.

The best results are obtained when welds are finished by hammering at 270° to 300° C. Design, particularly of tanks, should, so far as possible, provide for this.

Welded joints must be finally chromate pickled. This affords protection from corrosive attack, eliminates surface impurities which may set up electrolytic action, and provides a sound basis for paint, enamel, or lacquer that may be ultimately applied. Welded tanks, tubes, and all hollow products in elektron must be chromate pickled inside and outside.

When sheets or other products are delivered in the chromate-pickled condition, the light bronze-coloured coating should be removed by scraping where welds are to be made.

Considerable use is made of elektron for castings, stampings, and forgings, as it is here that the most benefit is obtained from the combination of the metal's extreme lightness and strength.

Surface Protection

The anodising process used for aluminium alloys is unsuitable for the protection of magnesium alloys from corrosion. Certain protective processes have been developed at the Royal Aircraft Establishment to serve a similar purpose. Prior to treatment the parts are prepared by dipping for a few seconds in 10 per cent. nitric acid. In the case of accurately machined work a half-hour immersion in a boiling solution of weak caustic soda is used. The actual protective surface is obtained by gently boiling the parts for six hours in a solution of potassium dichromate, potassium

alum, and caustic soda. On completion of the treatment the parts are washed and dried.

An alternative patented treatment is available which makes use of a different solution, and only requires thirty minutes. Either a brown or black film is produced on the surface, according to the alloy being treated. Both of these processes are known as "alkali chromate treatments." Yet another protective process, "selenium treatment," can be used. This consists of immersion at ordinary room temperature in a solution of selenium dioxide, sodium chloride, and water for five to fifteen minutes, according to the particular alloy. A reddish-brown film is produced. Treatments are also available for producing coloured surfaces.

STEELS

High-tensile Steel

Steels used in the aircraft industry fall into two main groups, namely, high-tensile alloys and non-corroding alloys. A list of the more common high-tensile steels, together with their composition, strengths, and uses are given in accompanying charts. Special qualities are obtained by the addition of less common metals such as vanadium, molybdenum, and chromium. For example, the addition of nickel increases the strength and toughness.

Stainless Steels

Stainless or non-corroding steels play an important part in the construction of airframes, being used extensively for smaller fittings such as eyebolts, sockets, and also wing spars and seaplane parts. When this material was first introduced, considerable difficulty was often experienced when attempting to work with it, but the more recent alloys can be handled with comparative ease, provided that certain rules are carefully observed. Stainless steels consist of iron together with a large percentage of nickel, to which is added one or more of the following metals: chromium, copper, tungsten, or molybdenum. The qualities of the finished product depend upon the metals alloyed with it, and some steels can be welded, stamped, or drawn more easily than others. Stainless steel can be obtained in the form of castings, forgings, sheets, bars, etc.

Welding Stainless Steel

When welding by the oxy-acetylene process great care must be taken to ensure that the flame is neutral, as an excess of either gas results in either a brittle or an unsound weld. The part to be welded should be thoroughly cleaned and, in the case of sheets, a stainless-steel rod of equal or heavier gauge than the work should be used. The weld should be softened and de-scaled after completion. Welds can also be made by the electric processes.

STEELS USED I

(EXCLUDING TH

Specification No.	Purpose	Composition: Carbon %	Silicon %	Manganese %	Nickel %	Chromium %	Molybdenum %
3S.1	Nuts, bolts, and lighty stressed machined fittings in general.	·15/·40	·30 max.	·50/·90	—	—	—
2S.2	Connecting-rod bolts, cylinder and crank-case bolts, main bearing caps, studs, and unions in the power unit. Miscellaneous bolts and nuts, fork ends, tube plug ends, sockets, and other stressed fittings in the airframe.			Composition not specified.			
3S.3	Lightly stressed plate fittings and wiring lugs.	·20/·25	·30 max.	·60 max.	(·30 max.)	—	—
3S.4	Stressed plate fittings, junction plates, levers, wiring lugs.	·25 max.	·30 max.	·60 max.	4·50/5·0	(·20 max.)	—
3S.6	Cylinder barrels, fuel-pump barrels in the power unit; bolts, nuts, and machined fittings in the airframe.	·35/·45	·30 max.	1·20 max.	1·0 max.	—	—
4S.11	Airscrew shafts and hubs, crankshafts, stressed bolts, miscellaneous nuts, etc., in the power unit; stressed bolts and nuts, fork ends, sockets, tube plug ends, wing roots, eyebolts, undercarriage mounting fittings, etc., in the airframe.	·25/·35	·30 max.	·45/·70	2·75/3·75	·50/1·0	(·65 max.)
2S.14	Valve tappets valve rockers, rocker rollers, camshafts, fuel-pump gears, water-pump spindles.	·10/·18	·30 max.	·90 max.	—	—	—
3S.15	Valve tappets, tappet rollers, push-rod heads, timing wheels, pinions.	·10/·15	·30 max.	·20/·60	2·75/3·50	(·30 max.)	—
2S.21	Lightly stressed bolts and nuts, eyebolts, tube plug ends, sockets and other machined fittings.	·25 max.	·30 max.	1·0 max.	—	—	—
2S.28	Connecting rods, hand-starter gears, magneto drive wheels, oil-pump gears, camshaft gears, supercharger gears.	·25/·32	·30 max.	·35/·60	3·75/4·50	1·0/1·50	(·65 max.)
S.65	Airscrew hubs, connecting rods, highly stressed bolts and nuts in the power unit; highly stressed bolts, nuts, and machined fittings in the airframe.	·22/·28	·30 max.	·35/·65	2·75/3·50	1·0/1·40	·65 max.
S.67	Airscrew reduction gears, auxiliary shaft gears, impeller gears, camshafts, oil-pump shafts, impeller shafts, sleeve cranks, valve rockers, tappets, tappet rollers, etc.	·08/·14	·30 max.	·35 max.	4·60/5·20	(·10 max.)	—
S.69	Bevel gear shafts, hand-starter shafts, pump-drive shafts, airscrew hub bolts, connecting-rod bolts, cylinder studs, valve rockers.	·35/·45	·30 max.	·50/·80	3·25/3·75	·30 max.	—
S.70	Cylinders.	·50/·60	·30 max.	·40/·75	—	—	—
S.71	Control levers, brackets, and similar details.	·25/·35	·30 max.	1·20 max.	—	—	—
2S.76	Cylinder barrels, fuel-pump barrels in the power unit; bolts, nuts, and machined fittings in the airframe.	·35/·45	·30 max.	1·20 max.	1·0 max.	—	—

AIRCRAFT CONSTRUCTION

Non-corrodible Steels)

Vanadium %	Tungsten %	Mechanical Properties: Max. Stress Tons/sq.in.	Proof Stress Tons/sq.in.	Elongation %	Red. of Area %	Izod Impact ft. lb.	Brinell No.	Form and Condition in which Supplied
—	—	35/45	—	15 min.	40 min.	—	—	Bright bars — cold rolled, drawn, or machined.
		55/65	—	18 min.	50 min.	40 min.	241/293	Bars, forgings, stampings — oil-hardened and tempered.
—	—	28 min.	(0·1% Pr'f) 16 min.	20 min.	—	—	—	Sheets and strip suitable for welding.
—	—	48 min.	(0·1% Pr'f) 40 min.	12 min.	—	—	200 max.	Sheets—softened.
—	—	35/45	—	20 min.	—	20 min.	146/201	Bars, forgings, stampings — normalised.
(·25 max.)	(1·0 max.)	55/65	—	18 min.	—	40 min.	248/293	Bars, forgings, stampings — oil-hardened and tempered.
—	—	32 min.	—	20 min.	50 min.	40 min.	—	Bars, forgings, stampings.
—	—	45/60	—	18 min.	45 min.	40 min.	—	Bars, forgings, stampings.
—	—	25/35	—	25 min.	50 min.	—	—	Bars—as rolled condition.
(·25 max.)	(1·0 max.)	100 min.	—	12 min.	25 min.	15 min.	444 min.	Bars, forgings, stampings — softened.
·25 max.	(1·0 max.)	65/70	—	17 min.	40 min.	35 min.	293/321	Bars, forgings stampings — oil-hardened and tempered.
—	—	40/60	—	20 min.	45 min.	50 min.	—	Bars, forgings, stampings.
—	—	55/65	—	18 min.	50 min.	35 min.	241/293	Bars, forgings, stampings — oil-hardened and tempered.
—	—	45 min.	—	18 min.	30 min.	—	197/241	Bars, forgings, stampings — normalised.
—	—	25/35	—	25 min.	50 min.	20 min.	109/163	Bars, forgings, stampings — normalised.
	—	40/50	—	22 min.	—	35 min.	174/223	Bars, forgings, stampings — oil-hardened and tempered.

(Reproduced by courtesy of Thos. Firth and John Brown, Ltd.)

Specification No.	*Purpose*	*Composition* Carbon %	Silicon %	Manganese %	Nickel %	Chromium %	Molybdenum %
S.77	Control levers, brackets, and similar details.	·25/·35	·30 max.	1·20 max.	—	—	—
S.79	Cylinders and cylinder liners.	·50/·60	·30 max.	·40/·75	—	—	—
2S.81	Crankshafts, connecting rods, airscrew shafts, hubs and bolts, reduction gears, and connecting-rod bolts.	·28/·35	·30 max.	·70 max.	3·0/3·75	·50/1·30	·50 max.
S.82	Airscrew reduction gears, supercharger gears, cam gears, crankshaft pinions, valve rockers, valve tappets, camshafts.	·18 max.	·30 max.	·50 max.	4·0/4·50	1·0/1·60	(·50 max.)
S.90	Airscrew reduction gears, cam gears, camshafts, gun-gear cams, gudgeon pins, magneto drive wheels.	·16 max.	·30 max.	·60 max.	4·50/5·0	·30 max.	·50 max.
3T.1	Struts.	·40 max.	·35 max.	1·75 max.	—	—	—
2T.2	Axle tubes, struts.	·25/·35	·35 max.	·45/·70	3·0/5·0	·50/1·5	(·50 max.)
3T.26	Racks, fairing supports, and other lightly stressed tubular structures.	·20 max.	—	—	—	—	—
2T.35	Fuselage and undercarriage parts, engine mountings, tail units, and other major welded tubular parts.	·30 max.	·35 max.	1·75 max.	—	—	—
2T.45	Fuselage and undercarriage parts, engine mountings, tail units, and other major welded tubular parts.	·30 max.	·35 max.	1·75 max.	—	—	—
2T.50	Pin-jointed fuselages, interplane and drag struts, tail spars, fuselage longerons, undercarriage compression legs, engine mountings, tail skids, and other mechanically jointed tubular details.	·50 max.	·35 max.	1·75 max.	(3·75 max.)	—	—
D.T.D.4A	Valve springs.	·40/·50	·30 max.	·50/·70	—	1·0/1·5	—
D.T.D.5A	Valve springs.	·70/·80	·30 max.	1·0 max.	—	—	—
D.T.D.87	Cylinder liners, crankshafts, and other hard-wearing engine parts (largely superseded by D.T.D. 306 and 317).	·35/·45	·45 max.	·65 max.	·25 max.	1·4/1·8	·10/·25
D.T.D.115	Valve springs and gudgeon pins.	·46/·56	1·6/2·1	·80/1·3	·40 max.	·10 max.	
D.T.D.124A	Spars, ribs, fuselage members, high-tensile plate fittings, wiring lugs, and other plate or built-up members in the airframe.	·25 max.	·30 max.	1·75 max.	(·20 max.)	—	—
D.T.D.126A	Bolts, nuts, studs, wing roots, eye-bolts, tube plug ends, sockets, and other medium stressed machined fittings.	·30 max.	·30 max.	1·75 max.	(·20 max.)	—	—
D.T.D.137A	Spars and spar-tension members, ribs, fuselage members, high-tensile plate fittings, wiring lugs, and other plate or built-up members.	·50 max.	·30 max.	1·75 max.	—	—	—
D.T.D.138A	Spars and spar-tension members, ribs, fuselage members, high-tensile plate fittings, wiring lugs, and other plate or built-up members.	·50 max.	·30 max.	1·75 max.	—	—	—
D.T.D.167	Fuselage structural parts, struts, and other mechanically jointed tubular structures.	·25/·45	·10/·30	·40/·80	—	·80/1·2	·15/·30

Vanadium %	Tungsten %	*Mechanical Properties* Max. Stress Tons/sq. in.	Proof Stress Tons/sq. in.	Elongation %	Red. of Area %	Izod Impact ft. lb.	Brinell No.	Form and Condition in which Supplied
—	—	30/40	—	25 min.	50 min.	25 min.	131/174	Bars, forgings, stampings — oil-hardened and tempered.
—	—	55 min.	—	15 min.	35 min.	—	235/285	Bars, forgings, stampings — oil-hardened and tempered.
(·25 max.)	(1·0 max.)	65/75	—	16 min.	—	35 min.	293/341	Bars, forgings, stampings — oil-hardened and tempered.
(·25 max.)	(1·0 max.)	85 min.	—	12 min.	35 min.	25 min.	—	Bars, forgings, stampings.
(·25 max.)	(1·0 max.)	65 min.	—	13 min.	—	30 min.	—	Bars, forgings, stampings.
—	—	35 min.	(0·2% Pr'f) 30 min.	—	—	—	159 min.	Tubes.
(·25 max.)	(1·0 max.)	85/100	78 min.	8 min.	—	—	388/514	Tubes.
—	—	(20)	(11)	—	—	—	—	Tubes.
—	—	{35 min. {30 min.	30 min. 25 min.	—	—	—	—	Tubes.
—	—	{45 min. {30 min.	40 min. 25 min.	—	—	—	—	Tubes.
—	—	50	45	—	—	—	229	Tubes.
15 min.	Copper ·15 max.	90/110	—	—	—	—	—	Wire, supplied by Firth-Brown in form of rod.
—	—	95/120	—	—	—	—	—	Wire, supplied by Firth-Brown in form of rod.
—	Alumin'm. ·90/1·3	55/65	—	17 min.	—	35 min.	241/302	Bars, forgings, stampings — oil-hardened and tempered.
—	—	90/105	—	10 min.	—	—	401/444	Bars—softened.
—	—	—	(0·1% Pr'f) 40/55	12 min.	—	—	—	Sheets and strip—oil-hardened and tempered.
—	—	40/55	(0·1% Pr'f) (31)	20 min.	—	35 min.	187/248	Bars, forgings, stampings — oil-hardened and tempered.
—	—	—	(0·1% Pr'f) 50/65	8 min.	—	—	—	Sheets and strip—oil-hardened and tempered.
—	—	—	(0·1% Pr'f) 65/75	5 min.	—	—	—	Strip — oil-hardened and tempered.
—	—	45 min.	(Y.P.) 40 min.	—	—	—	—	Tubes.

(*Reproduced by courtesy of Thos. Firth and John Brown Ltd.*)

Specification No.	Purpose	Composition: Carbon %	Silicon %	Manganese %	Nickel %	Chromium %	Molybdenum %
D.T.D.178	Structural parts of fuselages and undercarriages, engine mountings, tail units, and other major welded tubular structures.	·30 max.	·30 max.	·80 max.	—	·80/1·2	·15/·30
D.T.D.188	Medium-stressed bolts, nuts, studs, wing roots, eyebolts, tube plug ends, sockets, and other machined fittings in the airframe.	·40 max.	·30 max.	2·0 max.	—	—	(·60 max.
D.T.D.228	Crankshafts, airscrew shafts, and other hard-wearing parts of the power unit.	·25/·35	·35 max.	1·0 max.	1·0 max.	·50/1·5	0·9/1·5
D.T.D.247*	Valve seats, bolts, and studs holding down high-expansion light-alloy cylinder heads.	·70 max.	·50 max.	3·5/5·5	11·0/14·0	3·0 min.	(·50 max.)
D.T.D.254	Struts and other high-tensile tubular members.	·25/·35	·35 max.	·45/·70	3·0/3·5	·50/1·50	(·50 max.)
D.T.D.261	Cams.	·85/·95	·50 max.	1·7 max.	(·25 max.)	(·60 max.)	(·60 max.)
D.T.D.286A	Crankshafts, airscrew shafts, and other hard-wearing or highly stressed parts of the power unit.	·32/·48	·50 max.	·65 max.	·25 max.	1·4/2·5	·15/·50
D.T.D.299	Power unit bearing shells.	·15 max.	·30 max.	·60 max.	—	—	—
D.T.D.305	Lightly stressed welded tubular structures in the airframe.	·30 max.	·35 max.	1·75 max.	(·20 max.)	—	—
D.T.D.306	Master and articulated connecting rods, crankshafts, and airscrew shafts.	·15/·35	·35 max.	·65 max.	·30 max.	2·5/3·5	·30/·70
D.T.D.317	Cylinders and cylinder liners.	·15/·35	·35 max.	·65 max.	·30 max.	2·5/3·5	·30/·50
D.T.D.331	Variable-pitch airscrew spiders, high-tensile bolts, and other details in the power unit; highly stressed retractable undercarriage parts, wing roots, and other high-tensile machined fittings in the airframe.	·25/·40	·30 max.	·70 max.	3·0/4·5	·75/1·5	·65 max.

Figures in brackets indicate that the specification permits up to the stated maximum value, but that the element i not usually present.

NON-CORRODIBLE

(INCLUDING HEAT-

Specification Number	Purpose	Composition: Carbon %	Silicon %	Manganese %	Nickel %	Chromium %
S.61	Throttle-control rods and pins and control elbows in the power unit; lightly stressed machined fittings in the airframe.	·15 max.	·50 max.	—	1·0 max.	12·0 min.
S.62	Inlet valves, throttle-control rods and pins, pump spindles, carburetter parts and exhaust studs; bolts and nuts, wing fittings, fork ends, and eyebolts in the airframe.	·15/·35	·50 max.	—	1·0 max.	12·0 min.

Vanadium %	Tungsten %	Mechanical Properties: Max. Stress Tons/sq. in.	Proof Stress Tons/sq. in.	Elongation %	Red. of Area %	Izod Impact ft. lb.	Brinell No.	Form and Condition in which Supplied
—	—	45 min. 35 min.	(0·2% Pr'f) 30 min.	—	—	—	—	Tubes.
—	—	55/65	—	18 min.	—	40 min.	241/293	Bars, forgings, stampings — oil-hardened and tempered.
(·25 max.)	(1·0 max.)	55/65	—	18 min.	—	35 min.	248/293	Bars, forgings, stampings — oil-hardened and tempered.
(·25 max.)	(1·0 max.)	40 min.	—	25 min.	—	—	—	Bars, forgings, stampings — softened or in high-tensile condition.
(·25 max.)	(1·0 max.)	75/85	—	10 min.	—	—	341/388	Tubes.
(·35 max.)	(1·0 max.)	—	—	—	—	—	(Diamond Hardness) 672	Bars—softened.
·25 max.	Alumin'm. (·60 max.) Tungsten (1·0 max.)	55/65	(0·1% Pr'f) (43)	18 min.	—	35 min.	248/302	Bars, forgings, stampings — oil-hardened and tempered.
—	—	—	—	—	—	—	120 max.	Bars, forgings, tubes
—	—	30 min.	(0·2% Pr'f) 18 min.	—	—	—	—	Tubes.
(·25 max.)	Tungsten (1·0 max.)	60/70	—	17 min.	Reduction of Area. 35 min. (up to 2½" dia.) 25 min. (over 2½" dia.)		269/321	Bars, forgings, stampings — oil-hardened and tempered.
(·25 max.)	(1·0 max.)	45/55	—	20 min.	45 min. (up to 2½" dia.) 35 min. (over 2½" dia.)		207/255	Bars, forgings, stampings — oil-hardened and tempered.
·25 max.	(1·0 max.)	80/90	(0·1% Pr'f) (70)	14 min.	—	25 min.	363/415	Bars, forgings, stampings — oil-hardened and tempered.

Figures in brackets are given for information only and are not specified minima.

AERO STEELS

RESISTING STEELS)

Titanium %	Tungsten %	Mechanical Properties: Max. Stress Tons/sq. in.	Proof Stress Tons/sq. in.	Elongation %	Red. of Area %	Izod Impact ft. lb.	Brinell No.	Form and Condition in which Supplied
—	—	35/45	—	25 min.	50 min.	45 min. up to 2" dia. 25 min. over 2" dia.	152/207	Bars, forgings, stampings—oil-hardened and tempered.
—	—	46·52	—	20 min.	45 min.	35 min. up to 2" dia. 20 min. over 2" dia.	207/235	Bars, forgings, stampings—oil-hardened and tempered.

(Reproduced by courtesy of Thos. Firth and John Brown, Ltd.)

Specification Number	Purpose	Composition: Carbon %	Silicon %	Manganese %	Nickel %	Chromium %
S.80	Bolts and nuts, fork ends and pins, sockets, tube plug ends, wing roof fittings, eyebolts, wing-fixing lugs, undercarriage and engine mounting fittings, amphibian and retractable undercarriage parts, turnbuckles, levers, chain parts.	·25 max.	·50 max.	1·0 max.	1·0 min.	16·0/20·0
S.85	Medium-stressed plate fittings.	·15 max.	·50 max.	·70 max.	1·0 max.	12·0 min.
D.T.D.13B	Valves.	·40/·50	3·25/3·75	·40/·60	·50 max.	7·5/8·5
D.T.D.39	Exhaust manifolds and low-stressed plate fittings.	·10 max.	·50 max.	—	1·0 max.	12·0 min.
D.T.D.46A	Highly stressed spar constructions.	·12/·20	·50 max.	—	1·0 max.	12·0 min.
D.T.D.49B	Valves.	·35/·50	1·0/2·5	1·5 max.	10·0 min.	12·0/16·0
D.T.D.53	Lightly stressed machined fittings.	·10 max.	·50 max.	—	1·0 max.	12·0 min.
D.T.D.60B	Highly stressed spars, ribs, junction plates, and tank straps.	·20 max.	·60 max.	1·0 max.	1·0/3·0	16·0/12·0
D.T.D.61	Welding rod for S.80 group and low carbon 12% chromium steels.	·25/·55	2·0/3·5	0·6/1·25	24·0/28·0	15·5/19·0
D.T.D.97A	Lightly stressed members of tubular airframe construction and tubular rivets.	·15 max.	·50 max.	—	1·0 max.	12·0 min.
D.T.D.102A	Medium-stressed tubular members of airframe and undercarriage.	·15 max.	·50 max.	1·0 max.	1·0 max.	12·0 min.
D.T.D.146A	Junction plates and medium-stressed plate fittings and rib profiles.	·20 max.	·60 max.	1·0 max.	1·0/3·0	16·0/20·0
D.T.D.158	Wing ribs.	·08 max.	·50 max.	—	1·0 max.	13·0 min.
D.T.D.161	Rivets, split pins, locking wire.	·15 max.	·50 max.	1·0 max.	1·0 max.	12·0 min.
D.T.D.163A	Streamline wires.	·25 max.	·50 max.	1·0 max.	1·0/3·0	16·0/20·0
D.T.D.166A	Highly stressed wing and tail spars, ribs, struts, junction plates, wiring lugs, tank straps.	·20 max.	·20 min.	1·0 max.	6·0/20·0	12·0 min.
D.T.D.168	Highly stressed spar construction (except intricate spar sections).	·25 max.	·50 max.	1·0 max.	1·0 min.	16·0/20·0
D.T.D.171A	Low-stressed plate fittings, float and hull frames and plating, monocoque fuselage plating, cockpit and cabin trim.	·20 max.	·20 min.	1·0 max.	6·0/20·0	12·0 min.
D.T.D.176A	Low-stressed machined fittings in the airframe.	·20 max.	·20 min.	1·0 max.	6·0/20·0	12·0 min.
D.T.D.181A	Flexible wire rope for control wires.	20 max.	·20 min.	1·0 max.	6·0/20·0	12·0 min.
D.T.D.185A	Solid and tubular rivets, split pins, and locking wire.	·20 max.	·50 max.	1·0 max.	3·0 max.	16·9/20·0
D.T.D.189	Rivets, split pins, and locking wire.	·20 max.	·20 min.	1·0 max.	6·0/20·0	12·0 min.
D.T.D.195	Highly stressed spar construction (except intricate spar sections).	·12/·20	·50 max.	·70 max.	1·0 max.	12·0 min.
D.T.D.199	Highly stressed struts and amphibian undercarriage construction.	·25 max.	·50 max.	1·0 max.	1·0 min.	16·0/20·0

		Mechanical Properties						
Titanium %	*Tungsten %*	*Max. Stress Tons/sq. in.*	*Proof Stress Tons/sq. in.*	*Elongation %*	*Red. of Area %*	*Izod Impact ft. lb.*	*Brinell No.*	*Form and Condition in which Supplied*
—	—	55 min.	—	15 min.	—	25 min.	241 min.	Bars, forgings, stampings—oil-hardened and tempered.
—	—	30/40	(0·1%) 16 min.	15 min.	—	—	—	Sheets—heat-treated.
—	—	—	—	—	—	—	255/286	Forgings, stampings—oil-hardened and tempered.
—	—	28/35	—	—	—	—	—	Sheets—heat-treated.
—	—	—	(0·1%) 65 min.	—	—	—	—	Strips—softened.
—	2·0/4·0	—	—	—	—	15 min.	269 max.	Forgings—softened.
—	—	28·35	—	20 min.	—	25 min.	131/170	Bars—heat-treated.
—	—	55/70	(0·1%) 40/55	12 min.	—	—	235 max.	Sheets and strip—softened. Strip — air-hardened and tempered.
—	—	—	—	—	—	—	—	Rods.
—	—	28 min.	(Yield) 18 min.	—	—	—	—	Tubes—cold drawn and tempered or annealed.
—	—	35/45	—	—	—	—	153/207	Tubes—hardened and tempered, or drawn and blued.
—	—	40 min.	(0·1%) 30 min.	—	—	—	—	Sheets and strip—softened.
—	—	40 min.	(0·1%) 35 min.	—	—	—	—	Strip—as rolled or rolled and tempered.
—	—	30 min.	—	—	—	—	—	Rods, wires, rivets, splitpins—softened.
—	—	52/65	—	15 min.	—	—	235/302	Wires—hardened and tempered.
Present	—	52/70	40/50	—	—	—	—	Sheets and strip—cold rolled or cold rolled and tempered.
—	—	—	(0·1%) 60 min.	—	—	—	—	Strip — air-hardened and tempered.
		50 max.	—	—	—	—	—	Strip—softened.
Present	—	35 min.	(0·1%) 15 min.	—	—	—	—	Sheets and strip—softened.
Present	—	35 min.	(0·1%) 15 min.	30 min.	—	50 min.	—	Bars, forgings, stampings—softened.
Present	—	As specified by the manufacturer.				—	—	Wire—wire rope.
—	—	30/50	—	—	—	—	—	Rods, wires, tubes, splitpins—fully softened.
Present	—	30 min.	—	—	—	—	—	Rods, wires, rivets, splitpins—fully softened.
—	—	—	(0·1%) 55/60	—	—	—	—	Strip — air-hardened and tempered.
		45 max.	—	—	—	—	—	Strip—softened.
—	—	50 min.	(0·2%) 45 min.	—	—	—	—	Tubes—hardened and tempered.

(Reproduced by courtesy of Firth-Vickers Stainless Steels, Ltd.)

Specification Number	*Purpose*	*Composition* *Carbon* %	*Silicon* %	*Manganese* %	*Nickel* %	*Chromium* %
D.T.D.203A	Highly stressed tubular airframe members, interplane and drag struts, tail spars, fuselage longerons, undercarriage compression legs, engine mountings, and tail skids.	·10/·20	·50 max.	1·0 max.	1·0 max.	12·0 min.
D.T.D.207	Exhaust pipes, oil and petrol pipes; trailing edges, equipment frames, fairing supports in the airframe.	·29 max.	·50 min.	1·0 max.	6·0/20·0	12·0 min.
D.T.D.211	Fuselages, engine mountings, welded tail units, control tubes.	·20 max.	·50 min.	1·0 max.	6·0/20·0	12·0 min.
D.T.D.225	Pot rivets.	·20 max.	·60 max.	1·0 max.	3·0 max.	16·0/20·0
D.T.D.236	Aerial wire.	·20 max.	·20 min.	1·0 max.	6·0/20·0	12·0 min.
D.T.D.271	Magneto contact breaker and instrument springs.	·27/·32	·50 max.	1·0 max.	1·0 max.	12·5/13·5
D.T.D.282	Valves.	·30/·45	1·0/2·5	1·0 max.	6·0/10·0	17·0 min.
D.T.D.301	Tie rods.	·25 max.	·50 max.	1·0 max.	1·0/3·0	16·0/20·0
D.T.D.311	Valves.	·55/·65	1·4/1·7	·30/·60	Opt. ·50 max.	5·75/6·75
D.T.D.316	Exhaust manifolds and collector rings.	·30 max.	1·0 max.	1·0 max.	25·0/35·0	10·0/25·0
D.T.D.326	Springs.	·27/·35	·50 max.	1·0 max.	1·0 max.	12·0/14·0
D.T.D.328	Exhaust manifolds and collector rings.	·20 max.	·50 max.	1·0 max	75·0/85·0	12·0/15·0

In the case of arc welding, however, it is not deemed advisable to deal with work of less than 12-gauge thickness, and the current strength should be as low as possible. In the case of resistance or "spot welding," special machines are necessary, which automatically control the current strength and length of flow.

Soldering operations can be carried out in the usual way without much difficulty, and special fluxes are available for this purpose. Absolute cleanness in the surface to be soldered is essential.

Work-hardening

When subjected to a considerable amount of pressing, hammering, bending, and, in some cases, machining, a condition known as "work-hardening" is liable to occur. The metal becomes extremely hard and cannot be worked. Work-hardening can be avoided to a certain extent by carefully choosing the particular alloy recommended by the makers for that particular operation. However, if this condition should arise the only remedy is to soften the metal by thoroughly soaking it at a temperature of 1,000–1,150° C. in a furnace. This is followed by either air or water quenching.

Titanium %	Tungsten %	Mechanical Properties: Max. Stress Tons/sq. in.	Proof Stress Tons/sq. in.	Elongation %	Red. of Area %	Izod Impact ft. lb.	Brinell No.	Form and Condition in which Supplied
—	—	50/65	(0·2%) 45/55	—	—	—	229/293	Tubes—hardened and tempered.
Present	—	35 min.	(0·1% Pr'f, 15tonsmin., for Stressing purposes only.)	—	—	—	163 min.	Tubes—fully softened.
Present	—	50 min.	(0·2%) 45 min.	—	—	—	229 min.	Tubes—drawn or drawn and tempered. Weldable.
—	—	35/45	(0·1%) 20 min.	—	—	—	—	Sheets and strip—fully softened.
Present	—	As specified by the manufacturers.				—	—	Wire.
—	—	105/120	(0·1%) 75/85	—	—	—	—	Strip—hardened and tempered.
—	2·0/4·0	—	—	—	—	20 min.	302 max.	Forgings—softened.
—	—	52/64	—	15 min.	—	—	235/302	Rods — air-hardened and tempered.
—	—	—	—	—	—	12 min.	235/277	Forgings, stampings—air-hardened and tempered.
—	—	30 min.	(0·1%) 10 min.	(Thicker than 12 ga.) 30 min.	—	—	—	Sheets and strip—softened.
—	—	95/120	—	—	—	—	—	Wires—softened. Springs—hardened and tempered.
Iron % 10·0 max.	—	35 min.	—	30 min.	—	—	—	Sheets and strips—annealed.

(Reproduced by courtesy of Firth-Vickers Stainless Steels, Ltd.)

Scale is formed on the surface of the work by this heat-treatment, and a descaling process should be used for its removal. This is done by immersion in a solution of hydrochloric acid, nitric acid, water, and a special substance known as Ferro Cleanol II, heated to a temperature of 50–60° C. After removal it is only necessary to wipe away the loose scale. For hardening, the work should be heated, slowly and evenly, to between 950–1,000° C., and then quenched in oil or air.

Machining Stainless Steel

Stainless steel is not a hard material, although, due to the effects of work-hardening, some operators are inclined to consider it so. Provided that the proper precautions are taken machining can be carried out without difficulty. It is of the utmost importance that the tool is always kept feeding into the work, and on no account must it be allowed to "idle" or run free while in contact with the metal. If this is allowed to occur an extremely hard and glossy surface, which cannot be machined, is instantly produced at the point of contact. This applies to drilling, turning, boring and all operations except grinding.

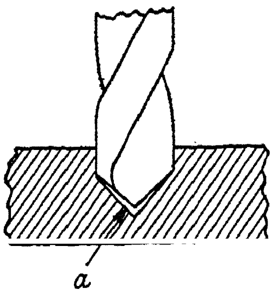


Fig. 3.—REGRINDING A DRILL POINT TO OVERCOME WORK-HARDENING

(*a*) is the bottom of the original hole.

Every form of vibration must be eliminated, as the blows delivered to the metal by the "tool chatter" rapidly produces work-hardening, and also dulls the edge of the tool. A keen cutting-edge should always be maintained and, at the first sign of dullness, the tool should be removed for sharpening. The tool, boring bar, or tool-holder should be as rigid as possible, and all machine-slides tightened. In the case of drilling operations the drill should be of the shortest possible length, and a constant heavy hand-feed employed. On no account must the drill be allowed to revolve in the hole without cutting.

Should work-hardening occur during drilling, the only solution, apart from softening the metal, is to regrind the drill point to a different angle and thus attempt gradually to overcome the hard surface (Fig. 3). The drill speed should be slightly more than half that employed on mild steel, and the feed should be as heavy as possible. Considerable skill and judgment is necessary to avoid breakages when dealing with small holes. Ordinary high-speed twist drills should be used, with the normal type of cutting edge.

Milling and Turning

The foregoing remarks regarding vibration and sharpness of the cutting edges also apply to milling operations. Wherever possible, the best-quality high-speed cutters should be used. Constant feeding pressure must be maintained and, as mentioned before, the cutting edges must not be allowed to rub on the work without cutting. For single point cutting tools, such as used for turning, planing, shaping and boring, the golden rule is to provide as much rake as can be used without causing chatter. In other words, the edge should be as keen as possible. A rake of 20° can be taken as standard for ordinary lathe surfacing operations.

Chapter II

WORKS METHODS

IT will be realised that the manufacturing methods employed by various firms often differ, as it is only natural for individual minds to develop ideas along different lines. Only the very largest firms in this country manufacture the complete airframe in their own works, and even these have many of the units made by smaller outside sub-contracting firms. Some of these are large enough to possess special expensive equipment, but the smaller sub-contracting firm mainly employs hand-operations for shaping the various components. This includes the use of wheeling machines, pillar drills, and hand-operated presses.

A certain amount of hand-shaping will always be necessary, but the new technique aims at reducing airframe manufacture to a mass-production job, as in the case of motor-cars.

For this reason it is not proposed to deal in detail with the older methods, but to concentrate more on the new methods being developed by the larger firms, both in this country and abroad.

Templates

After the design of the machine has been approved, the first stage of production consists of making the various templates necessary to ensure that the components, often made in different parts of the works or by different sub-contract-

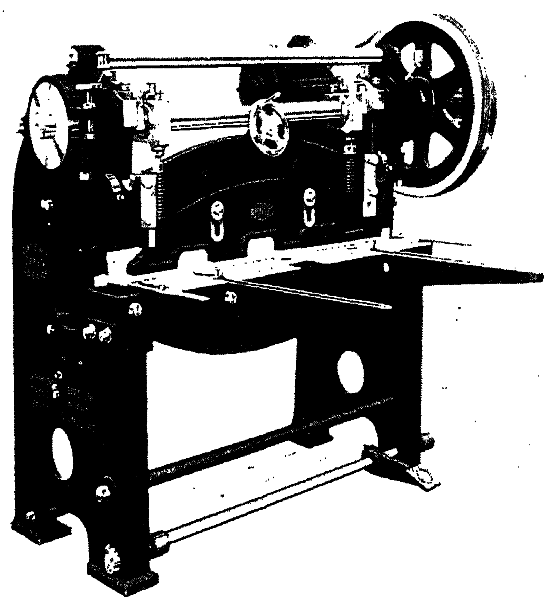


Fig. 4.—SHEETS AND COMPONENTS WITH STRAIGHT EDGES ARE RAPIDLY CUT WITH A GUILLOTINE SUCH AS THIS. (*Joseph Rhodes & Sons, Ltd.*)

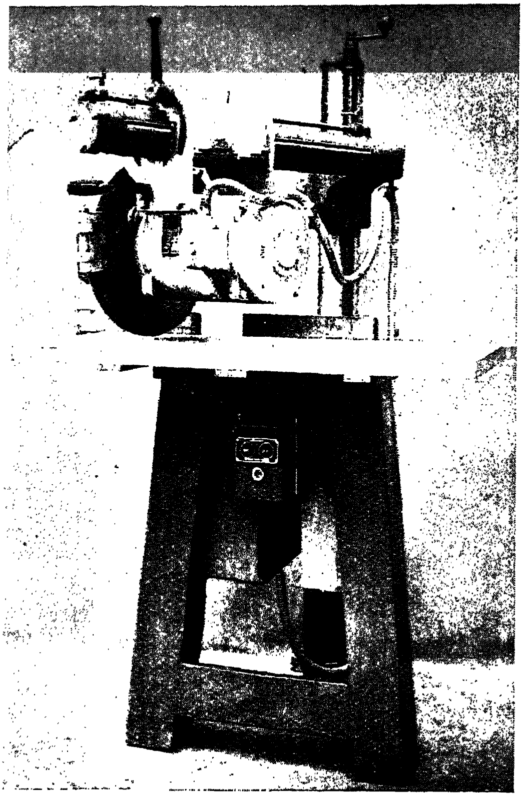


Fig. 5.—This sliding saw has been specially built for cutting off light alloy sections, such as are used for aircraft work. (*Midland Saw and Tool Co. Ltd.*)

ing firms, will fit together when they meet for assembly. This can be done in two ways. The first, and older, method consists of making a large number of detail drawings from the main drawings showing the general design of the machine, and obtaining from these the template dimensions. Apart from the additional cost and time required to make these detail drawings there is always the possibility of errors creeping in.

A more modern method, widely used in America and now being adopted in this country, is that known as "lofting." This consists of laying out to full size end and side elevations of the main units, such as the wing and fuselage. The template maker is able to obtain his measurements direct from these, and can check his work by placing it on the layout. As can be seen, this requires considerable space, and the tendency now is to set aside a large room solely for lofting, using the floor as a "drawing board." A coat of light coloured paint is applied to the floor before use, so that the lines will be clearly seen.

An alternative method consists of laying-out the design on large wooden or metal sheets, painted white. This possesses the advantage that the lay-outs can be stored in a small space, or hung on the walls. The complicated shape produced at the junction of the wing and fuselage can be obtained with considerable accuracy, and the exact size, shape and position of such items as the windows, doors and stringers can be determined. Two types of templates are made at this stage, one being the "tool template," giving the shape of the tool used for pressing or forming the piece of sheet to its final shape, and the other the "development template," showing the outline of the component before carrying out

the above operations. These will be described later in more detail.

Cutting Out

Sheets are supplied in standard sizes, usually of 6 by 2 ft., and 6 by 3 ft., and from these are cut the shaped pieces from which the various components are made. In the smaller works, and also for small quantities in the large shop, the parts are cut out by similar methods to those employed for ordinary sheet-metal work, namely, with hand and power shears. High-speed band saws (Fig. 6) are also used, the sheet being held on the machine table by hand and guided around the saw to suit the contours.

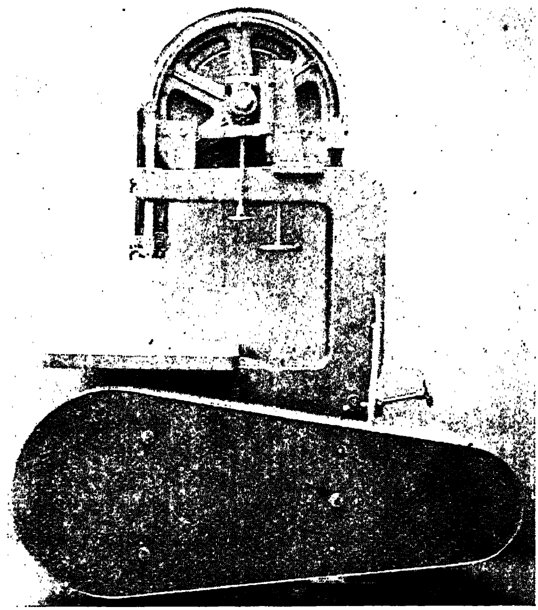


Fig. 6.—A HIGH-SPEED "MIDSAW" BAND-SAWING MACHINE SUITABLE FOR CUTTING SHEETS AND SHAPED PANELS

In Fig. 7 is a Desoutter portable pneumatic nibbler, specially developed for aircraft work. This tool does not actually cut the sheet, but nibbles its way forward by punching small crescent-shaped pieces of metal at a speed of 2,500 cuts per minute. This results in a clean $\frac{7}{32}$nds inch wide cut, free from burrs.

If the tool is to be used for internal work, such as cutting out inspection panels in wings, portholes in fuselages, or hand-holes in fuel tanks, it is necessary to first drill a 1-in. hole. The cutting portion of the head is inserted, and from this position the tool can be guided to cut out any desired shape. Curves with a radius as small 1 in. can be cut.

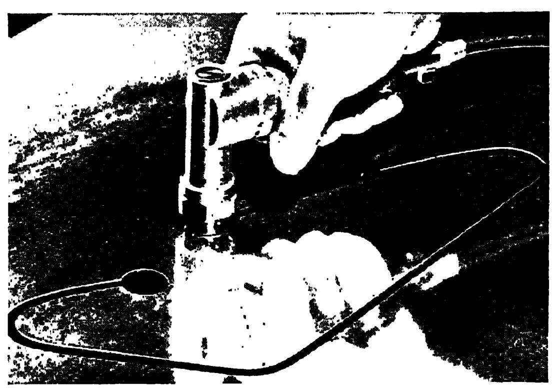


Fig. 7.—A HIGH-SPEED PORTABLE NIBBLER FOR CUTTING OUT AIRCRAFT PANELS. (*Desoutter Bros. Ltd.*).

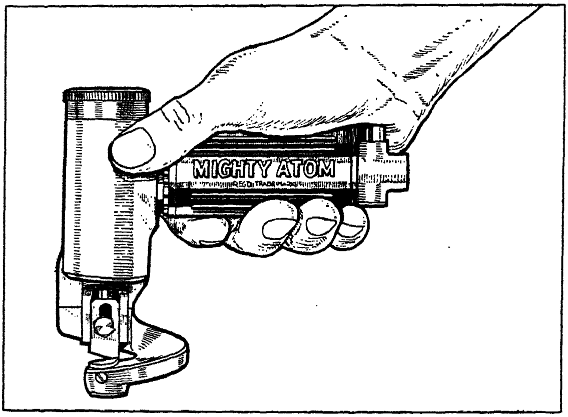


Fig. 8.—A PORTABLE "MIGHTY ATOM" SHEAR FOR TRIMMING SHEETS UP TO 18 S.W.G.

Fairly accurate results can be obtained by following a line marked on the work, but where a higher degree of accuracy is required the use of a template is advisable. This is a piece of plywood made either $\frac{3}{8}$ in. larger or smaller than the hole, and held on the sheet by clamps. It is then only necessary to guide the tool so that one or other side of the circular portion seen just above the sheet is in contact with the template.

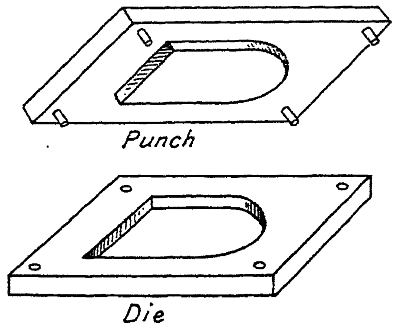
In addition to its use for cutting-out holes or pieces of sheet prior to assembly, this tool is also widely used for cutting out panels, etc., during actual assembly. Complete control is maintained from a button-switch operated by the base of the hand and, with its weight of only 2 lb. and cutting speed of 10 ft. per minute, this tool is very easy to manipulate.

Fixed-head nibbling machines are also used for cutting-out purposes. These obviously are unsuitable for parts already assembled on the plane, and their use is confined to operations prior to forming, welding, riveting, etc. The theory of operation is similar to that of the portable nibbler already mentioned, and consists of cutting by means of a rapidly moving punch. To avoid the production of rough ragged edges on the work, only a small feed is used.

Another type of cutting equipment makes use of two small shear blades, approximately 1 in. wide, instead of a punch. One blade is fixed and the other oscillates rapidly up and down at 1,000–1,500 cuts per minute. This gives a cutting speed in the region of 6 ft. per minute. Special attachments are available with both types of machine, to enable circles and straight lines to be cut with considerable accuracy. A portable version of the shearing machine is also available (Fig. 8). More use is now being made of rotary-wheel shears for cutting-out and trimming purposes. This machine, which has been used for many years in the automobile and steel industries, carries two bevel wheels of hardened steel. One is power-driven and the two are adjusted to give a shearing effect at their edges. Curved shapes can be cut with particular ease on this machine.

Blanking

To those familiar with the automobile industry, the most obvious solution to the cutting-out of sheet metal components lies in the use of



Figs. 9 and 10.—A SIMPLE FORM OF PUNCH AND DIE FOR BLANKING NOSE RIB FORMERS

press tools. This operation, known as "blanking," can be followed from the sketch in Figs. 9 and 10. The shape of the desired part is cut out of a thick piece of metal, termed the "die," whilst the material is cut away from another piece so that it will just fit into the die. This latter is a "punch." The die is secured to the lower stationary portion of a press, and the punch is bolted to the upper platen, which can be raised and lowered. Thus, if a piece of sheet is laid on the die and the punch lowered with considerable force, a piece of similar shape to that of the punch will be cut out. This is "blanking," in its most simple form. In practice, however, the operation is not quite so simple, as careful attention must be paid to such factors as the amount of clearance between the form of the punch and die, and also to the amount of taper given to the working edges of the tools.

The foregoing remarks serve to illustrate the process in a simple manner. Blanking is an expensive operation if only a few components are required, as the cost of making the tools is very high. If, however, the quantities are sufficiently large this undoubtedly is the most economical process, as a very large number of parts can be blanked in a short time, once the dies are made. Small parts are often produced in this manner by using a hand press. Sometimes the tools are fastened in the press, but in many cases they are loose.

If larger quantities are required the tools are used in a heavier power press, the punch being raised and lowered by mechanical means. As the size of work which can be handled in a hand press is very limited, the power press is also used for blanking large components. Successful experiments have recently been made in the use of very heavy presses for blanking parts which were formerly considered too large to be produced by this method.

Rubber Presses

As mentioned earlier, the cost of press tools is very heavy, with the result that blanking is not economical except when very large quantities are required. This has led to the development of an entirely new method of blanking which requires only one tool, usually the punch, and an hydraulic press. Some firms, however, prefer to use a die instead of a punch. The top platen of the press is recessed and fitted with a 6-in. thick pad of hard rubber, covering the entire surface. The tool is laid on the lower platen, loose, and on this is placed the piece of sheet metal.

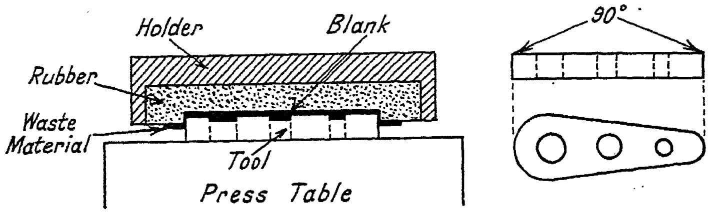


Fig. 11.—Blanking a former with a rubber pad

On the right is a plan and elevation of the simple tool used for this operation.

As the rubber pad descends its first action is to hold the metal firmly on the tool and then, under the influence of increasing pressure, the portions of the rubber not pressing against solid metal are forced downwards.

This can be understood from the sketches in Fig. 11, where it will be seen that the elasticity of the rubber allows it to accommodate itself to tools of any shape. Even steel sheets of $\frac{3}{32}$-in. thickness have been sheared by this process. The tools consist of flat pieces of hardened steel plate, shaped to the contour of the required blank. It is not necessary to provide clearance or cutting rake, the top and sides being at 90° to each other.

Routing

Another process, of widely different character, has been developed with considerable success for cutting-out components prior to forming. This is known as "routing," and is a specialised form of vertical milling. In Fig. 12 is a Wadkin router, which represents the latest development in this type of machine. A vertical pillar, capable of rotation, carries a long horizontal arm, which can be moved backwards and forwards through the special arm bearing. Mounted on one end is the routing head, consisting essentially of an electric motor driving a chuck and spindle at a very high speed. Fitted in the chuck is an end milling cutter.

Bolted to the head is a large double handle by means of which the operator guides the cutter. The arm is very accurately balanced, and the vertical pillar is carried on ball bearings. Thus, with very little effort the operator is able to move the head backwards and forwards and follow the outline of the work. Plywood templates are used to guide the cutter, these being the development templates mentioned earlier, which allow for the amount of metal to be later bent over as flanges. Steel-bushed jig holes indicate the position of the holes in the finished component.

A number of sheets, depending on their gauge thickness, can be routed simultaneously. In most cases the average number is 8–12. These are piled on a stout board, and the template laid on top. A few

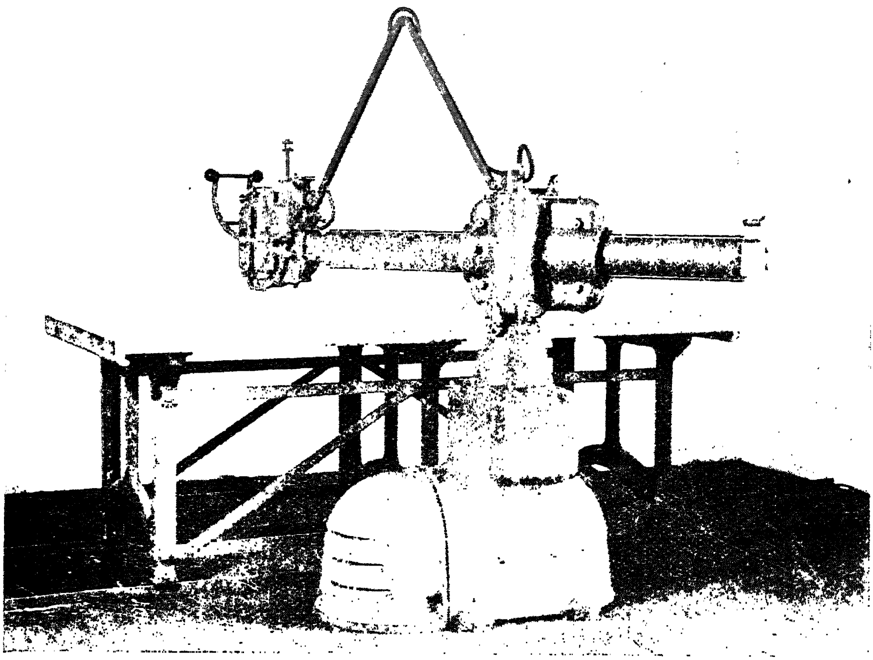


Fig. 12.—A RADIAL-ARM ROUTING MACHINE DEVELOPED FOR AIRCRAFT WORK

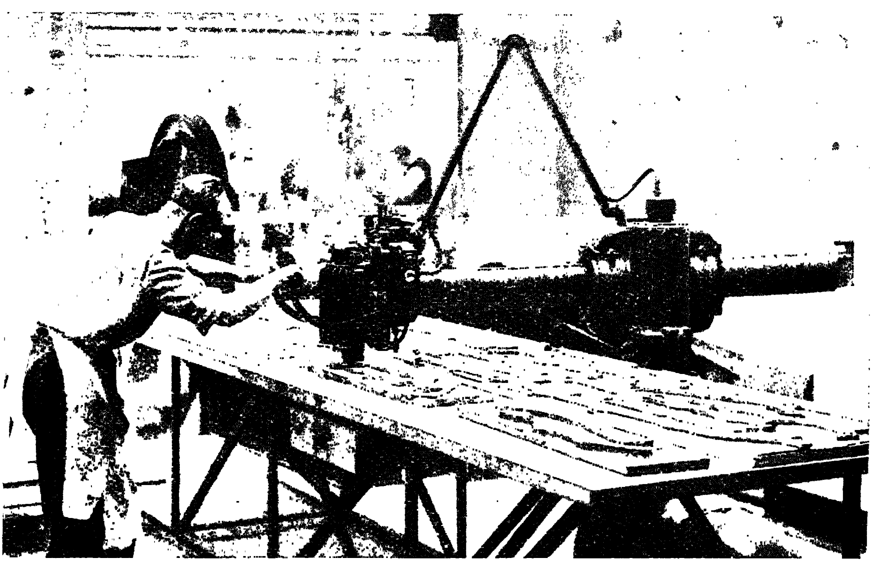


Fig. 13.—SHOWING THE MANNER IN WHICH A NUMBER OF ROUTING TEMPLATES CAN I ARRANGED, SO THAT THERE IS THE MINIMUM OF WASTE MATERIAL. (*Wadkin Ltd.*)

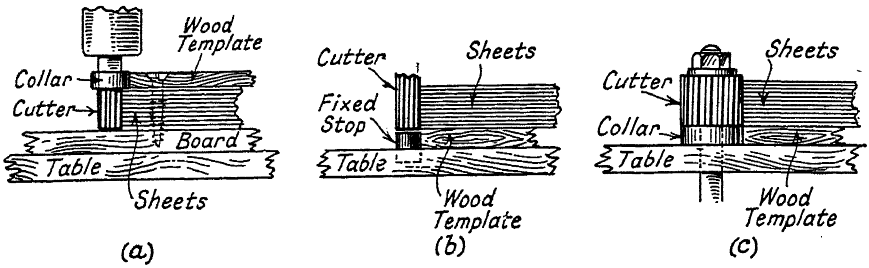


Fig. 14.—METHODS OF ROUTING AND SPINDLING

(*a*) Radial-arm method, where the work is stationary and the cutter is moveable.
(*b*) Fixed-head routing. The sheets and templates are moved around the fixed stop-pin.
(*c*) Spindling is very similar to (*b*), as the work is moved around the vertical spindle which carries the cutter.

of the holes are then drilled so that the bundle of sheets can be screwed to the board. As a rule several templates are laid on at a time, in the manner shown in Fig. 13. By suitable arrangement of these it is possible to use the entire sheet without leaving large pieces of waste material. Sufficient room must, of course, be allowed for the cutter to pass between the templates.

A very similar machine (Fig. 15) has been developed for drilling the sheets, the main difference being a slight alteration in the design of the head. The chuck carries a drill and, behind this, is a pneumatic claw-clamp which descends to hold the sheets with a force of 100 lb. before each hole is drilled. A bush with a tapered nose can be fixed to the clamp to provide easy location and to guide the drill. This is used in conjunction with templates not fitted with the steel bushes mentioned earlier. Control of both drilling and routing machines is from a push button on the head. It is common practice to arrange a routing and drilling machine side by side, these being used in conjunction with two worktables provided with steel legs which enable them to be easily pushed along rails running in front of both machines. Thus, after drilling and screwing to the board, the work can be moved along to the router without disturbing the setting (Fig. 16). A new machine has recently been designed with a drill head at the other end of the arm carrying the router head, so combining two machines in one. It is only necessary to swing the arm through 180° in order to change from one operation to another. In this case, of course, it is unnecessary to move the table.

Fixed to the top of the cutter, above the flutes, is a collar which remains stationary when the machine is running, and the operator manipulates the head so that this is in contact with the profile of the template. Thus, having fed in the cutter to the depth of the bottom sheet, the work can be cut out in a very short time, without the aid of skilled labour. In practice, it is usual to follow twice around the template, using first a guide

collar approximately $\frac{1}{8}$ in. larger in diameter than the cutter. This is in the nature of a "roughing cut," and leaves a small amount of metal for removal at the second cut, this time using a collar of the same diameter as the cutter. Some firms adopt a slightly different method, and fit loose bushes to the top of the actual cutter. This is kept in contact with the side of the template. In this case it is necessary to make the template slightly less than the development size, to compensate for the difference in outside diameter between the bush and cutter.

Fig. 15.—Drilling aircraft panels with a special Wadkin radial-arm machine

Note the use of bushed template to avoid the necessity for marking out the holes. (*Wadkin Ltd.*)

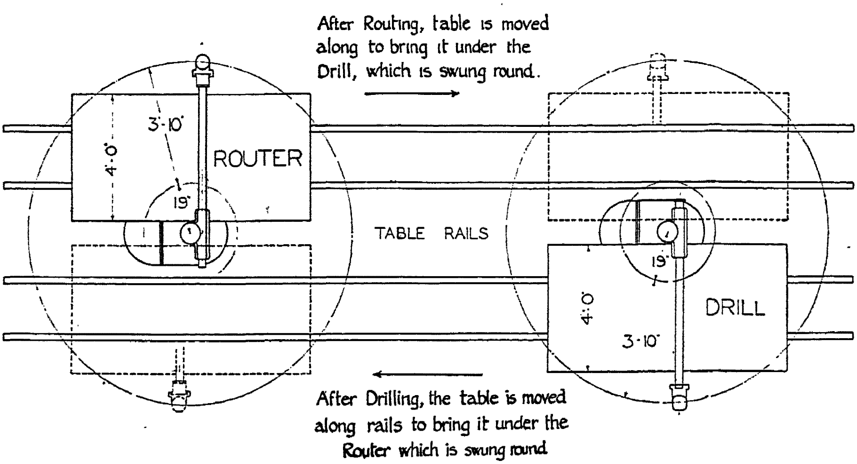


Fig. 16.—Diagrammatic layout of radial arm routing and drilling units for duralumin sheets. (*Wadkin Ltd.*)

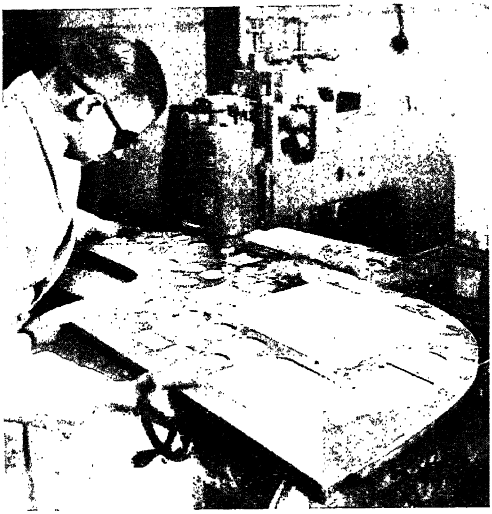


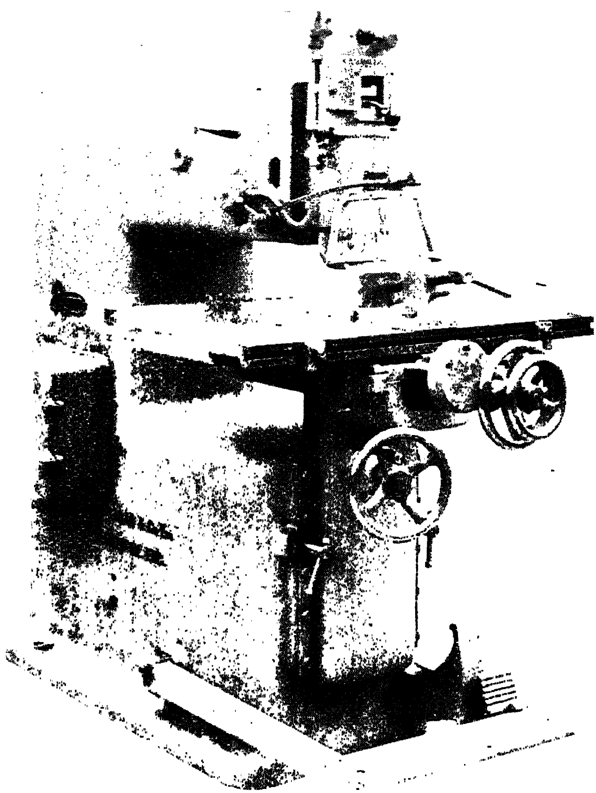
Fig. 17.—ROUTING WITH A FIXED-HEAD MACHINE

In this case the template is at the bottom. (*Wadkin Ltd.*)

Fixed-head Routers

Another type of routing machine is the fixed-head model (Fig. 17), which is practically identical with the type of router used in the wood-working industry. As will be seen, the cutter, an end mill, revolves in a fixed position over a table and, around this, the work is moved by hand. In this case the metal sheets are fastened on top of the template. Projecting from the table, directly below the cutter, is a steel stop pin, and the operator manipulates the assembly so that he is always pressing the edge of the template against it. This is the reverse method to that employed with the radial arm machine. When roughing-out the work a collar is fitted over the pin, the latter being of the same diameter as the cutter.

Fig. 18 (*below*).—A TYPICAL FIXED-HEAD ROUTING MACHINE FOR MACHINING PARTS FOR WOODEN AND METAL AIRCRAFT. (*J. Sagar & Co. Ltd.*)



A cutter speed in the region of 24,000 r.p.m. is used. At the base of the machine is a foot-operated treadle, pressure on which lowers the cutter head to the required depth, so leaving the operator with both hands free to move the work. The depth of vertical feed is controlled by stops.

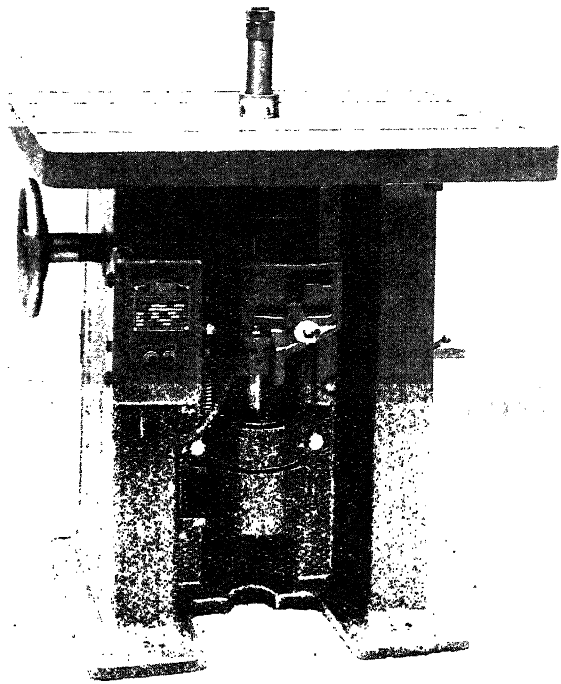


Fig. 19.—A SAGAR SPINDLING MACHINE SUITABLE FOR SHAPING AIRCRAFT SHEETS

Spindling

Yet another modern method employed for cutting-out work is that of "spindling" (Fig. 19), which is also well known in the woodworking industry. This is not strictly a cutting-out process, but is concerned with shaping sheets previously sawn or cut to an approximate shape. Essentially, the machine consists of an electrically driven vertical cutter-spindle, projecting above a work table. Fixed to the free end is either a coarse milling cutter or an ordinary woodworking cutter. Below the cutter is a steel guide-bush of the same diameter. Several sheets are screwed to a wooden template, as before, and the template is kept in contact with the bush.

Forming

Following the cutting-out operation the burrs, if any, are removed by filing or scraping. At this stage certain holes are drilled, unless the routing process has previously been used, in which case the holes are already drilled. In the case of rivet holes for minor components only sufficient are drilled to allow the part to be bolted in place for assembly, the remainder being drilled "in situ." If the quantity permits, several sheets are stacked together on an ordinary pillar drill, as the number of holes is usually quite small. On the other hand, for small quantity production, the holes may be drilled through each part individually, using

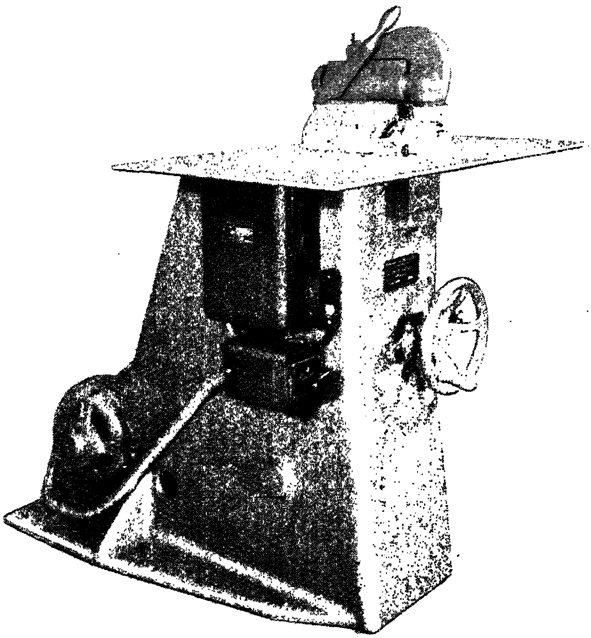


Fig. 20.—THE ERCO SHEET METAL FORMING MACHINE USED FOR FLANGING AIRCRAFT PARTS. (*A. C. Wickman Ltd.*)

either a pillar or a portable drill. The position of the holes is indicated by a template, to which the sheet is secured by light clamps.

The next stage is that of forming the blank to its final shape. In the earlier days of aircraft engineering this work was all done by hand, i.e. panel beating, a slow and expensive process. The shortage of skilled labour, coupled with the low output, led to the introduction of mechanical methods of forming which have proved very successful. It must be pointed out that panel beating is still necessary, but not to anywhere near the same extent as previously. For small quantity production mechanical processes are not suitable, as the cost of tools and special plant is too large. Also, certain shapes cannot yet be produced by the new methods, although in certain of these later cases the component is "roughed" by mechanical means and then finished by panel beaters, thus reducing both production time and cost.

Forming Machines

A new type of machine has been developed for forming or flanging edges of sheet metal in cases where the contour is so irregular that hand work would otherwise have to be employed. This is the Erco sheet metal former (Fig. 20) which can be used to form practically any regular or irregular shape.

The material is formed through the hammer-like blows of a small brake against a holding-down tool, delivered at a speed of 250–500 strokes per minute. A small part of the sheet is brought up at each stroke of the brake head, which strikes upward against the holding-down tool. After each stroke the work is automatically released, so that the operator

Fig. 21.—A RUBBER PRESS FOR FLANGING THE EDGES OF PANELS, FORMERS, RIBS, AND OTHER PARTS. (*J. Shaw & Sons Ltd.*)

can feed it through the machine. A different set of brake and hold-down tools are required for each height of flange and thickness of material, also for special shapes. These can be changed in a few seconds by loosening a single screw in each tool. Parts such as metal ribs, tank ends, and monocoque fuselage components are among those regularly formed with this machine.

Rubber Press

One of the most simple methods of mechanical forming is by the use of the "rubber press" mentioned earlier, this being used for flanging and producing shallow forms. Actually, this process was first developed for forming, and then later used also for blanking. The top platen carries a thick rubber pad, and the tool is laid on the bottom platen. The tool is very simple, consisting merely of a piece of mild steel or zinc alloy plate shaped to the contours of the component. Steel tools are cut from plate to approximate shape by bandsawing, and then filed or milled to final dimensions. The softer type of tool is finished by spindling on the machine shown in Fig. 19. A fairly large radius is provided on the top edge, corresponding to the radius always found on

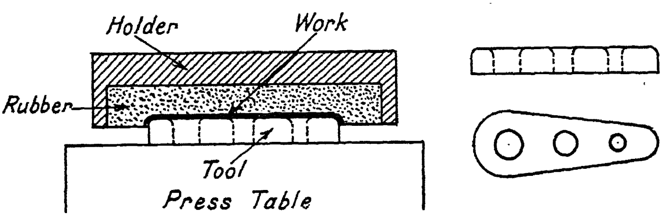


Fig. 22.—FORMING FLANGES ON THE COMPONENT SHOWN IN FIG. 11, FOR WHICH OPERATION A RUBBER PRESS IS USED. ON THE RIGHT IS A PLAN AND ELEVATION OF THE TOOL

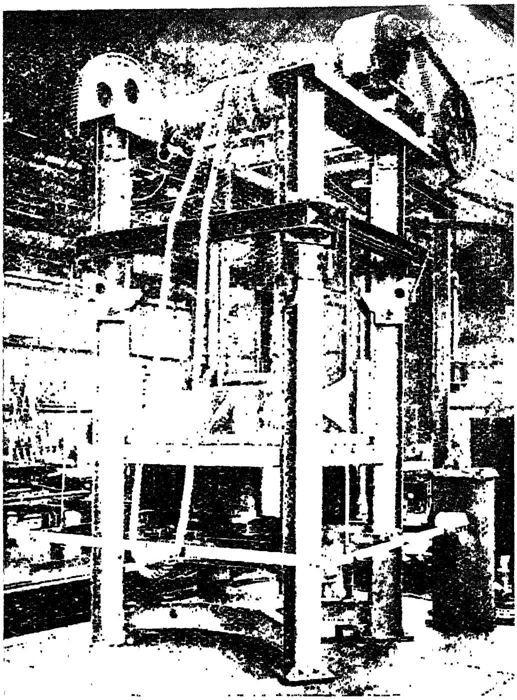


Fig. 23.—A DROP STAMP FOR SHAPING SHEET METAL
This employs soft-metal dies. (*Geo. W. King Ltd.*)

flanged components. The majority of flanges are less than 1 in. in depth, and thus these tools are usually cut from 1-in. to $1\frac{1}{4}$-in. material.

A lower pressure than for blanking is used, the presses being rated at between 1,000 and 1,500 tons capacity. These machines can handle parts as large as 4 by 6 ft. or more, and, as much of the work is less than a foot in length, several parts can often be formed simultaneously. The blanks are laid on the tools, and the rubber pad descends comparatively slowly. At the bottom of the stroke the pressure is maintained for a short period, after which the top platen ascends. It will be realised that the elastic nature of the rubber allows it to accommodate itself to any minor variations in height, and thus a difference of $\frac{1}{4}$ in. between the height of the various tools being used at the same time does not affect the accuracy of the results.

Drop Stamping

Only components of a comparatively shallow nature can be handled on the rubber press and so, for deeper or more intricate work or parts made from hard material such as stainless steel, a special type of drop hammer has been developed (Fig. 23). The drop stamp is similar in operation to that used for forging, but is considerably wider between the guides and of lighter construction. Overhead is an electric motor and suitable mechanism which winds the belt fastened to the tup. The tup is the steel block to which the top die is fastened. The sides of the hammer are machined to act as guides to the falling weight, and the base forms the table.

Two dies are used to shape the sheet metal, the female shape being bolted to the table and the male to the tup. Thus, by placing a piece of sheet on the lower die and striking a few blows with the top die (by dropping it several times from a height) the component is quickly formed

to shape. Some hammers are operated by pulling a rope, which causes an overhead clutch to come into action and wind up the belt, whilst others are controlled from a foot treadle. This latter type possesses the advantage of leaving the operator with both hands free. Naturally, the greater the height from which the top die is dropped the greater will be the force with which it strikes the work. Suitable safety catches are incorporated to prevent the tup from being raised too high and damaging the hammer.

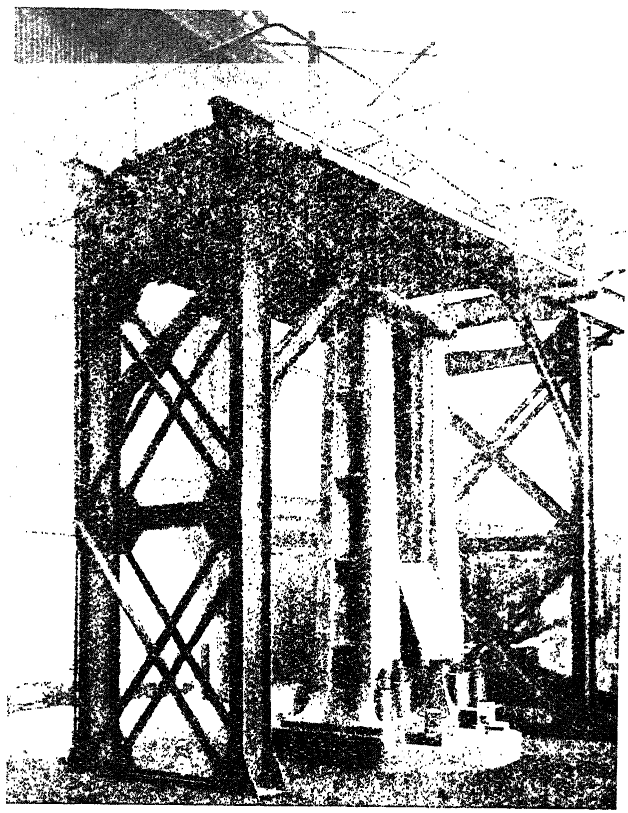


Fig. 24.—A LARGE DROP STAMP USED FOR FORGING
This strikes a blow of more than 100 ft./tons. (*B. & S. Massey Ltd.*)

From earlier remarks it will be evident that the production of dies is, normally, an expensive item, and is not an economical proposition unless very large quantities of parts are required. However, an entirely different type of die is used with these special hammers, which can be produced very cheaply and quickly, and so warrant their use for small-quantity production. These are cast in lead and zinc by ordinary foundry methods. The lower die is made first, by pouring molten zinc into a sand mould. Before putting any component into production, it is customary to make a trial part by ordinary panel-beating methods, to ensure that the design is satisfactory. This sample is often used as the pattern from which the sand mould is made, thus ensuring accuracy and also eliminating the cost of special wood patterns.

The top or male die is cast from the bottom die by pouring an alloy of lead and antimony into the impression, using it as a mould (Fig. 25).

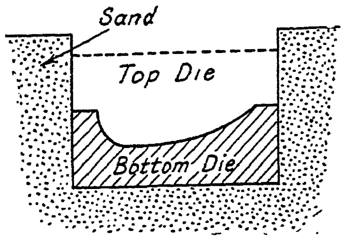


Fig. 25.—METHOD OF CASTING A LEAD TOP DIE, USING THE ZINC BOTTOM DIE AS A PATTERN

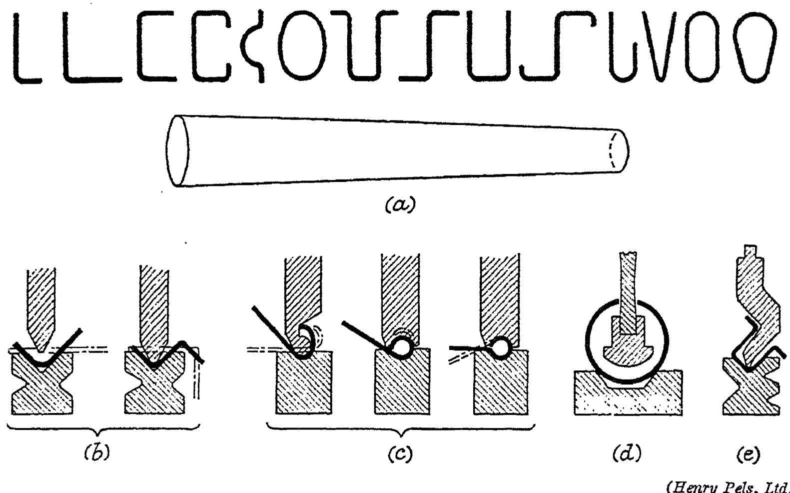
By suitably embedding the bottom die in sand, additional metal can be provided to give weight and strength. In most cases the difference between the contraction of the metals provides sufficient clearance between the dies to allow for the thickness of the sheet which is to be stamped. If, however, thick-gauge material is to be used, a piece of mild steel sheet is placed between the dies, when they are fastened in the hammer, and stamped to shape. This is tough enough to produce sufficient clearance between the softer dies. Fifty to a hundred parts can be produced from a pair of dies before it is worn too much for further use, the actual figure varying according to the nature of the material and the shape of the work. After completion of the order the dies can be melted and the metal used to produce another set.

Pressing

Another obvious forming process is that of pressing with the ordinary equipment used for sheet steel. Here, again, the question of quantity is the deciding factor, due to the expense of the dies. Up to the present time this type of pressing, using heavy presses similar to those employed for automobile and other large work, is not in general use, although a certain number of components are now being regularly made by this process. Undoubtedly, large components at present made up from several smaller parts will, in the near future, be pressed out as single pieces, thus enabling their production in at least one-tenth of the time taken at present.

However, pressing is widely used as a means for producing smaller parts, using lighter machines. Considerable economy has been made possible by the use of hard-wood dies in place of those of expensive steel. The manufacturing cost is also considerably less, as the die material can be machined more easily. This special wood is built up from thin laminations in a similar manner to plywood, each layer being impregnated with a solution of a synthetic resin. The sheets of wood, approximately $\frac{1}{8}$ in. thick, are placed in piles under a very powerful hydraulic press and compressed. This compressed or hard wood has a shear strength of 6,000–8,000 lb. per square inch, and a tensile strength in the region of 45,000 lb./sq. in., from which it will be seen that it is practically equivalent to good-quality mild steel. In fact, the material can only be machined or shaped by using metal-working tools.

Naturally, the cost of this wood is less than steel of similar dimensions. The thickness varies, according to the number of laminations, up to a maximum of 3 in., and if a greater thickness is required, several pieces



26.—PRESS BRAKE WORK

(*a*) Typical sections which can be produced on a folding press.
(*b*) Method of folding a Z section.
(*c*) Showing the changes of tool required for a hinge.
(*d*) Producing a circular section.
(*e*) A universal tool which can be used for many purposes.

can be glued or bolted together to form a large block, which can be shaped to the contours of the required component. The wood die so constructed can be used to produce between 1–200 parts, according to the metal in use. If the work is to be formed from fairly hard metal, or if a larger number of parts are required, it is customary to cover the working faces of the wood die with steel sheet.

Folding Presses

Apart from the shaped components mentioned in the foregoing pages, a fairly large quantity of strip sections are required for the construction of an all-metal plane. These are lengths of material formed to special shapes, such as shown in Fig. 26. For this type of work a folding press (often termed a "press brake") is used, and the method of operation can be followed from the various sketches. Two shaped tools are fixed in the press brake, the lower female tool being stationary and bolted to the table, whilst the upper tool is attached to the sliding ram which moves with an up-and-down motion.

These tools, which may be up to 16 ft. in length and reciprocate at 20–30 strokes per minute, are not always shaped to the same contour as the required section, and do not press the work in the same way as the other types of presses mentioned earlier. They are used to fold or bend the strips of metal, previously cut to length on a guillotine shear. This can be followed from the example in Fig. 26*b*, showing the folding of

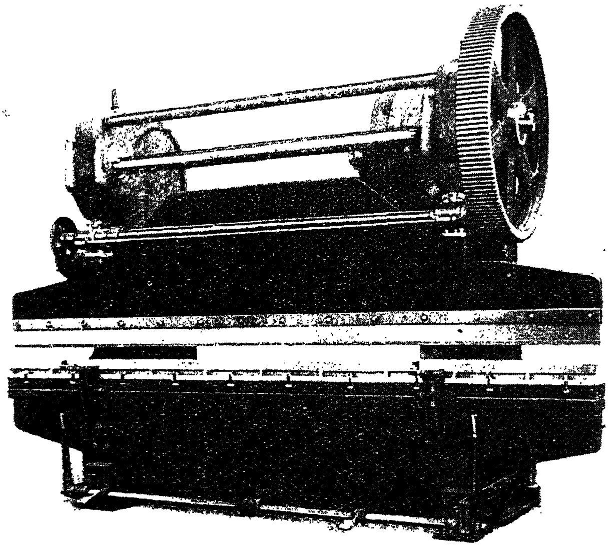


Fig. 27.—A FOLDING PRESS, PROVIDED WITH EXTENSIONS WHICH ALLOW THE BENDING OF VERY LONG SECTIONS. (*Joseph Rhodes & Sons Ltd.*)

a simple Z section. The flat strip is laid over a tool resembling a vee block, and a stroke from the upper tool produces the first bend. The partly formed section is then laid on the tool in the manner shown by the dotted line in (*b*) and provided with the second bend. Stops are provided either behind or in front to locate the strip in a position parallel to the tools.

In many cases a change of tools is required for each bend, as in the case of the hinge in (*c*). For tubular or curved sections the strip is gradually given its shape by moving it around after each stroke. A cranked universal tool with many applications is shown in (*e*).

For building up wing spars and other units use is often made of solid sections. These are manufactured by a process known as "extruding," and are supplied to the aircraft manufacturer in lengths ready for cutting to final size. Extruded sections are designed to give the maximum strength and rigidity, combined with the minimum of weight (Fig. 28).

Drawing

Many spars of special section are made by drawing lengths of strip material through formed rollers or dies. This process, known as "drawing," is particularly suitable when the length of section is too great to allow its production in a press brake, or if the section is very complicated. Several such sections are shown in Fig. 29*a*. If the section is fairly simple, the forming may be carried out with a single die or roller, but for more complicated shapes it may be necessary to use six, seven, or more. In

Fig. 28.—TYPICAL EXTRUDED SECTIONS

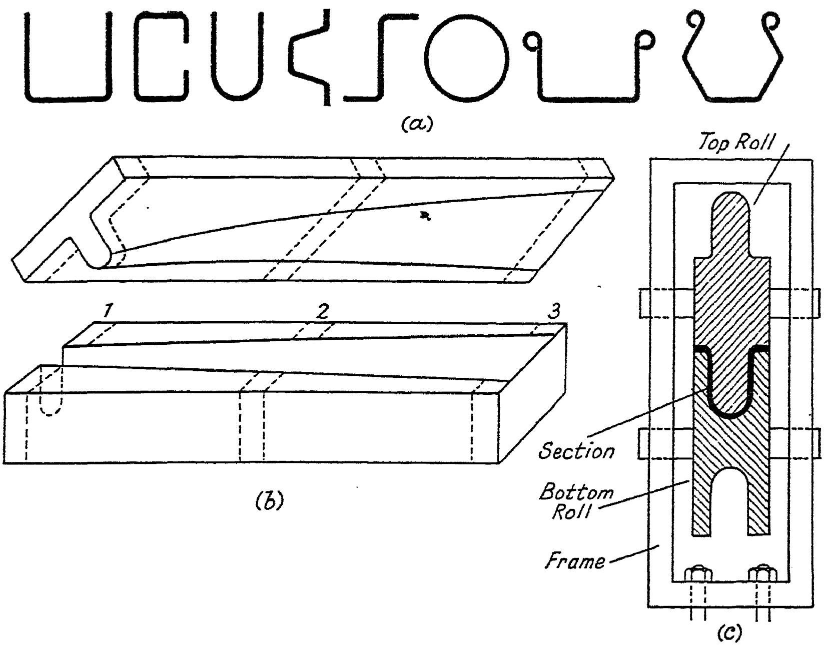


Fig. 29.—Methods of drawing sections

(*a*) A group of simple drawn sections.
(*b*) A solid die for drawing a *U* shape. This may be between 12 and 20 in. in length. Plate dies consist of narrow pieces of the shapes indicated at 1, 2, and 3.
(*c*) The general arrangement of a pair of rolls for drawing a special *U* section.

this case the shape is obtained progressively, more form being given at each stage.

A draw bench consists essentially of a long bench or similar structure on which are mounted a pair of rails. Sliding on these is a carriage provided with a suitable device for firmly gripping one end of the strip of metal. By means of a motor-driven endless chain the carriage can be moved along the rails, drawing the strip with it. At one end of the bench is either a die or a battery of rollers, through which the strip is drawn, thus forming it to shape. If a solid die is used, this consists of a block of cast iron or steel with an impression of such a shape that the flat strip leaves it as a finished section (Fig. 29). This means, of course, that the impression gradually changes from a shallow groove to the desired section.

To avoid the expense of this solid die several pieces of plate can be used, these being provided with impressions corresponding with various positions on the solid die. By arranging these plate dies vertically and at a suitable distance apart the same result can be obtained as with the solid die. A straightening operation is usually necessary after draw-

ing with dies, this consisting merely of applying tension to one end of the finished section. The length of section which can be produced by this method is limited only by the length of the draw bench, which may be in the region of 60–80 ft. Lubrication is provided to the strip by felt rollers or other means as it passes through the dies.

Rollers

Dies are not particularly suitable for light metals, such as the aluminium alloys, due to the possibility of scratched and weakened surfaces being produced by the entry of foreign matter between the dies. Thus for this type of work it is usual to employ rollers, these being held in a series of cast-iron frames to form a battery. Much faster production speeds can be obtained, and this may be as high as 1,600 ft. per hour. The rollers rotate freely, and adjustment can be made from the top roller to alter the pressure. Special machines, however, have recently been developed in which the rollers are driven by power, thus obviating the necessity for the sliding carriage to pull the strip.

In some instances a plate die is arranged adjacent to the last roller to give the final shape to the section. Special draw benches have been designed in which the raw strip unwinds from a coil, passes through rotary shears, which cut it to the exact width, and then enters the rolls. Occasionally it is necessary to arrange the rolls vertically to obtain successful results, this depending on the contour of the section.

Spinning

Certain curved work cannot be formed by any of the processes already mentioned, two examples of this being radial-engine cowlings and airscrew spinners. These are produced by "spinning," a process which is carried out in a special type of lathe. Fastened to the face-plate is a tool, generally of wood, shaped to the contours of the work, over which the sheet metal is gradually worked by means of hand-operated steel tools. The metal is previously cut out and welded to form a ring of approximate shape, this being held against the face-plate by pressure from a disc mounted on the tailstock.

The work rotates at a very high speed and, under the pressure exerted by the tool, is gradually forced to the shape of the wooden tool or former. Due to the ductile character of the aluminium and most of its alloys, the metal flows to the required shape without much difficulty. During spinning operations grease is liberally applied to the work-surface for lubrication purposes. Spinning is carried out in two stages, the first consisting of a "roughing" operation, whilst during the second the uneven surface is made perfectly smooth with a planishing tool. Very few, if any, aircraft works at present do their own spinning, but place this work with outside sub-contractor specialists.

Chapter III

METHODS OF JOINING COMPONENTS

HAVING dealt with the forming of the various components, it is proposed to follow on with the joining together of these into sub-assemblies or small units. This can be done by either riveting or welding. If the former process is employed, it must be preceded by a drilling operation. Drilling can be divided into two classes, i.e. fixed head and portable.

The term "fixed head" is meant to include all types of drilling machines, as distinct from portable equipment. Most of the machine-drilling is done with the ordinary sensitive column type of drill, often described as a "pin drill."

Several drill heads are often mounted side by side over a common table and fixed on a common base (Fig. 30). This is particularly useful when holes of different sizes are required in one type of component, as the need for constant drill-changing can be eliminated by fitting the various sizes of drills in the different heads. Thus it is only necessary to slide the work from one head to another when a hole of different size is required.

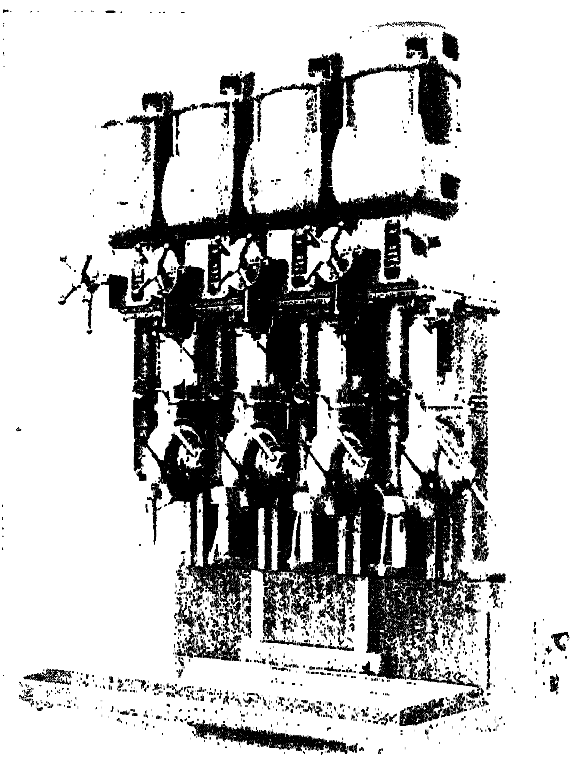


Fig. 30.—A NEW TYPE OF FOUR-SPINDLE PILLAR DRILL.
(*A. Herbert Ltd.*)

Light radial-arm machines have been specially developed for drilling wing-

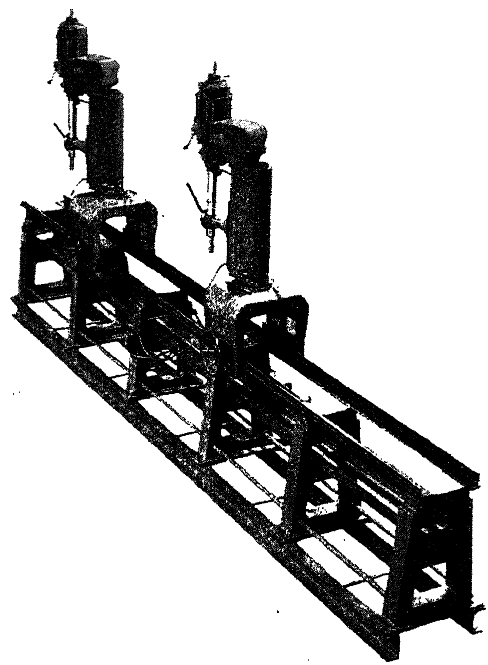


Fig. 31.—This machine is specially designed for drilling wing-spars, stringers, and similar long parts. (*Jones & Shipman Ltd.*)

spars and other long parts. These are much lighter than the ordinary radial machines used in engineering workshops, and are little more than high-speed sensitive drills carried on a swinging arm. One such machine is shown in Fig. 31. In this case two independent motor-driven drill heads with speeds variable up to nearly 3,000 r.p.m. have been used. The heads can be moved along the bed by the hand-wheel seen on the side, and the actual drill spindle can be swung to either side of the 20-foot bed.

It will be seen that the base of the head is of box shape, so that the spars can be fastened between the two slides and the head moved over them. There is sufficient room to allow a box-type jig to be used, the upper face of which is provided with steel-bushed holes to guide the drill. An interesting foreign spar-drilling machine has been designed which carries a radial drilling head and also a radial-arm riveting head. These slide along a 15-ft. bed and enable spars to be drilled and riveted at one setting, by swinging the unwanted head out of the way.

Portable Drills

The majority of the holes in any airframe are drilled with portable equipment, such as shown in Fig. 32. Much of this class of work is done by drilling through templates, which may be either of the steel-bushed

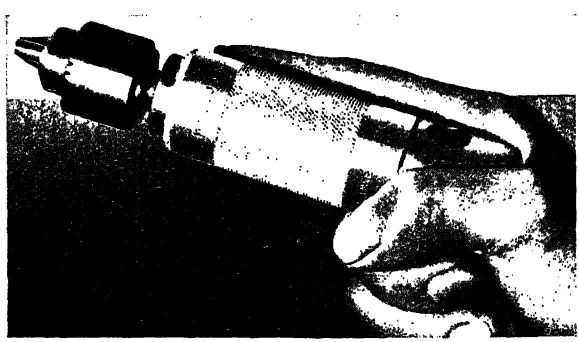


Fig. 32.—A Desoutter portable drill for straightforward work

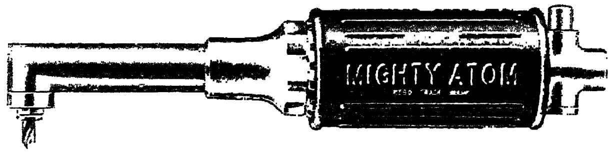


Fig. 33.—THE SHAPE OF THE HEAD OF THIS DESOUTTER DRILL ALLOWS IT TO BE USED IN DIFFICULT POSITIONS

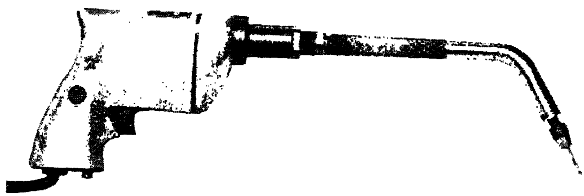


Fig. 34.—BY FITTING THIS SPECIAL ATTACHMENT HOLES CAN BE DRILLED IN POSITIONS WHICH ARE OTHERWISE INACCESSIBLE. (*Black & Decker Ltd.*)

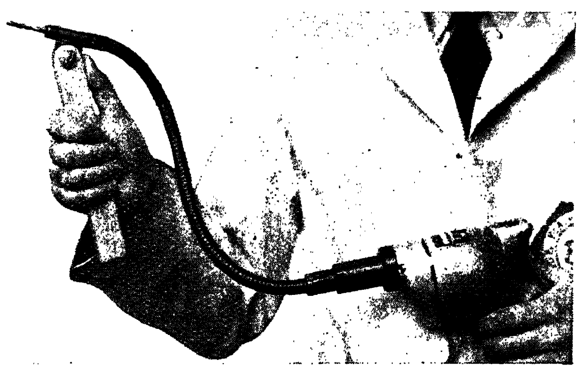


Fig. 35.—THIS INGENIOUS FLEXIBLE ATTACHMENT IS VERY USEFUL FOR ASSEMBLY WORK. (*Black & Decker Ltd.*)

type, or may consist merely of the mating part in which the holes have been previously drilled. Many types of bushed templates are used, each varying according to the shape of the component and the ingenuity of the tool designer. Some firms favour the use of wooden jigs, fitted with steel bushes, for larger work. This is mainly on account of cheapness, and the ease with which wood can be shaped.

Some drilling jigs, such as used for leading edges and wing tips, are very complicated and cost several hundreds of pounds. These generally consist of a stout base or table, built up from angle iron, the top of which is shaped to the same contours as the underside of the component. This may be achieved by bolting a shaped wooden block to the table, or by bending steel strips. The work is a snug fit on this top, to avoid distortion by the pressure exerted during drilling.

Over the work is placed a light steel frame, also shaped to the contours of the work, which carries steel-bushed holes corresponding to those required for riveting. Provision is made by screw-clamps or other means to hold the top template and the work firmly together. Very little skill

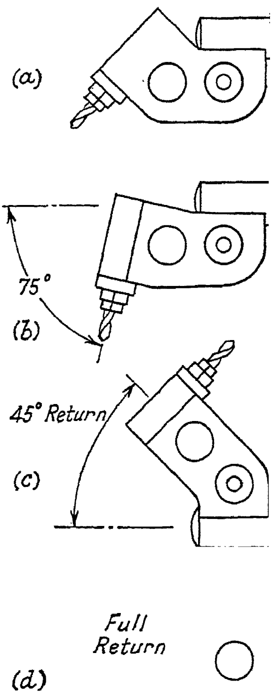


Fig. 36.—A DOUBLE-JOINTED "MIGHTY ATOM" PORTABLE PNEUMATIC DRILL FOR AIRCRAFT WORK

is required on the part of the operator, who has merely to place the point of the drill in the bushed holes, and push it through the component.

Much of the portable drilling is done during actual assembly of the work. If two parts of difficult shape are to be riveted together, it is considerably easier and more accurate to drill all the holes in one piece and then, during assembly, drill the holes in the other piece by using the first as a template. It will be realised that it is not merely a case of drilling one or two holes, but often 50–100, or more.

Considerable difficulty is sometimes experienced when using the drill in a very confined or difficult position, and special equipment or attachments are available for this work. One such tool is the Desoutter "Mighty Atom" close-corner drill (Fig. 33). This can be used for drilling holes up to $\frac{3}{16}$ in. diameter in awkward and otherwise inaccessible positions. It is possible to drill a hole, the centre of which is within $\frac{5}{16}$ in. from a shoulder or face standing at right angles to the work. Weighing only $1\frac{1}{4}$ lb. and running at 2,500 r.p.m., the drill can be easily held and manipulated by one hand.

Another model of this particular tool has the drill head set at 30° to the extension shaft, instead of 90°. With the ordinary "Mighty Atom" model, the axis of the drill is parallel with the hand-grip. Yet another variation of this drill is the double-jointed type in Fig. 36, which enables holes to be drilled to within $\frac{1}{4}$ in. of the inside face of a right angle. Other arrangements of the head are also shown, from which it will be observed that it can be used to drill from the rear of the work. A further type of specially developed aircraft drill is the Black & Decker "Holgun"

electric drill, adapted for working in difficult positions (Figs. 34–5). In one case a rigid extension spindle, with the chuck set at 30°, is fitted to a standard-type tool, whilst on the second drill a flexible shaft is provided. This can, naturally, be bent to suit any position.

Telescopic Jig Drill

As mentioned earlier, considerable use is made of jigs for drilling, and for this reason the special Desoutter jig drill in Fig. 37 is of particular interest. The handle and stem is similar to that in Fig. 32, but the nose portion is of unique design, being arranged to telescope or slide inside the stem when pressed against a template. The end of the nose is tapered, hardened, and provided with a hole which acts as a guide to the drill. Thus, if pressure is applied to the nose, it will recede, leaving the drill projecting through the end.

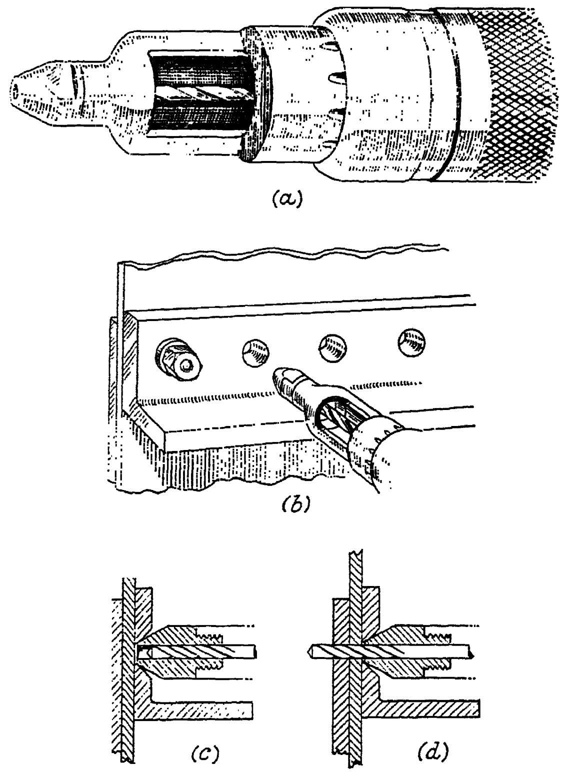


Fig. 37.—DRILLING HOLES FOR A RIVETED JOINT CONSISTING OF TWO SHEET-EDGES AND AN EXTRUDED ANGLE BAR

A special Desoutter telescopic-nose drill is used, and the previously drilled angle piece is employed as a template.

(*a*) The telescopic nose. (*b*) The sheets and angle assembled for drilling. Two bolts hold the parts in position. (*c*) A side section showing the drill nose before pressure is applied. (*d*) As pressure is applied the drill feeds forward.

As the actual nose does not rotate, the tool can be used in conjunction with plywood or mild steel templates provided with countersunk guide holes. It is only necessary for the operator to insert the tapered nose into the countersunk hole, and then press the tool. The drill is instantly accurately located, and no skill is required on the part of the operator. When the pressure is released the nose automatically projects again, and covers the drill point. It will be seen from the sketch that the nose

taper is slightly less than that of the countersunk hole. This tool has a speed of 13,000 r.p.m., a weight of only $2\frac{1}{2}$ lb., and can be used on light-alloy sheets up to $\frac{3}{32}$ in. thickness. Models with lower speeds are available for drilling steel.

Riveting

At the present time riveting is more widely used than any other operation for the fastening together of small units, sub-assemblies, and complete assemblies. Riveting can be carried out by several methods, the most simple being by the use of a punch, suitably recessed at the end, and a hand-hammer. This is far from satisfactory, as the effect of hammering is transmitted to the area of the sheet immediately surrounding the rivet, and causes slight stretching. Although this is not very serious in the case of a single rivet, the cumulative effect on along row can cause considerable deformation.

In general, the material to be riveted is comparatively thin, and unless special precautions are taken when dealing with long seams, the riveting will "grow" or "creep." For example, if an operator commences to rivet from one end he will discover, after inserting seven or eight rivets, that the remaining holes in the two sheets do not coincide, and that further rivets cannot be inserted. To avoid this trouble it is essential to fasten the work together with service bolts, these being inserted at regular intervals along the seam. Every sixth hole is usually sufficient.

It is now common practice to use special quick-action locating pins or clips in place of bolts. There are a number of different types on the market, all possessing the common features of holding the sheets firmly together and of being capable of quick insertion and removal. In addition to the above precautions each alternate hole should be riveted first. If more than one operator is working on a long seam, riveting should commence simultaneously from both ends and the middle. If only one operator is engaged on the work, he should try to obtain a similar result by moving from one position to another. These hints apply to all types of both hand and machine riveting.

More satisfactory results can be obtained from hand riveting by using equipment such as shown in Fig. 38. These consist of a pair of pincer jaws which close on the rivet by means of hand-operated levers. The tool is so designed that the hand pressure is considerably multiplied at the jaws. Consideration of the various assembly sketches throughout this section will show that riveting is very difficult in certain locations, and for this reason the tool-jaws must be capable of operating in practically every conceivable position. Most of the heads of the tools in Fig. 38 can be turned around to any angle in relation to the hand lever, and different shapes are available for different types of work.

To avoid excessive fatigue the tools are sometimes suspended from overhead wires, or fixed to a pedestal.

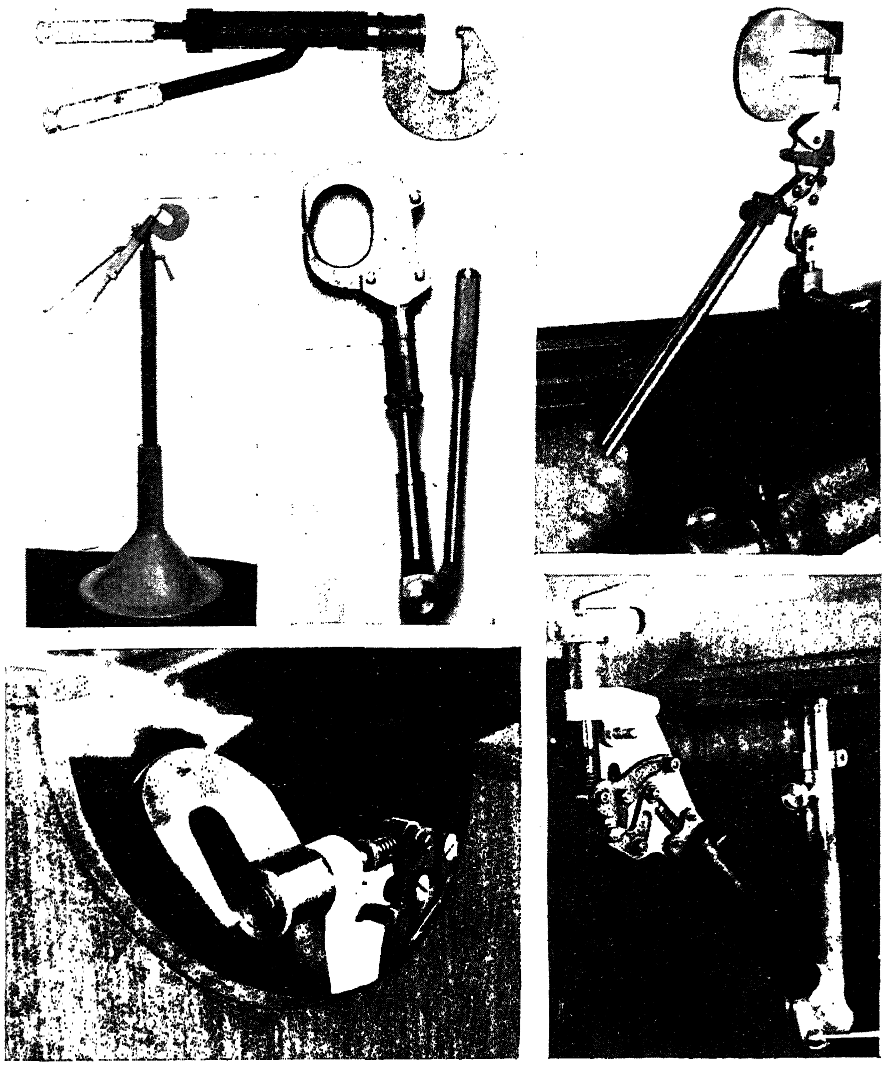


Fig. 38.—HAND-OPERATED RIVETING EQUIPMENT ARRANGED FOR SUSPENSION, PEDESTAL, AND BENCH MOUNTING

Some are made to be held in a vice or fixed to a bench. A pneumatically operated version of this tool is also available, the workman being able to hold it in one hand and close the jaws by movement of a finger switch.

Tubular Rivets

Solid rivets are not particularly suitable for very thin sheets, and for this work extensive use is made of tubular or "pop" rivets, consisting

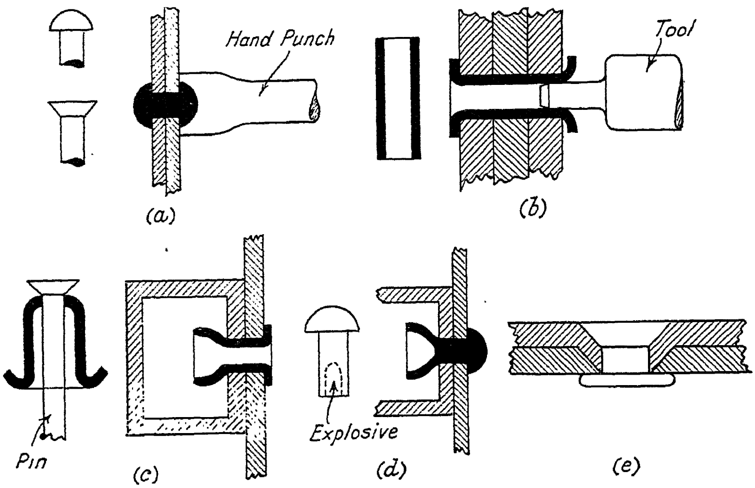


Fig. 39.—VARIOUS TYPES OF AIRCRAFT RIVETS AND THEIR USE

(*a*) Snap-head and countersunk head. (*b*) Tubular rivet. (*c*) Patented "pop" rivet. (*d*) Explosive rivet. (*e*) Flush rivet.

simply of a small tube (Fig. 39B). The end can be swaged over by a hand-operated tool, similar to those already mentioned, fitted with tapered jaws. Another method of closing these rivets is by "spinning" the ends, one of the jaws of the tool being held in rotating chuck.

Although, at a first glance, tubular rivets may appear to be considerably weaker than the solid rivet, it must be remembered that rivets are only intended to take shear stresses. Under these circumstances, the hollow rivet is quite satisfactory, although it is not quite as strong as the solid type. However, this is offset by certain important advantages when used for sheets of less than 22 s.w.g., which give it a decided advantage over the solid rivet.

One important feature of the "pop" rivet is that it can be used in positions which are inaccessible from one side, such as when fastening ribs to tubular spars. The rivet, together with a small steel taper-head pin, is inserted in the hole (Fig. 39C), and the free end of the pin is held in a special tool. The nose of the tool presses against the outer end of the rivet, whilst an internal chuck pulls the pin through the rivet. As a result, the inaccessible side of the rivet is formed to a bell-mouth shape, the pulling force keeping the sheets firmly together. Each pin can only be used once, the tapered head being damaged as it is pulled through. In the case of larger rivets, i.e. above $\frac{3}{16}$-in. diameter, the head of the pin is stronger and of a different shape, which enables the same pin to be used repeatedly. Several other types of tubular rivets are also in use.

Explosive Rivets

An explosive rivet has recently been introduced from abroad for riveting from inaccessible positions. This is a solid rivet, with the end recessed and filled with explosive. It is only necessary to insert the rivet from the accessible side of the hole and press firmly against it with a heated holding-up tool. In a few seconds the temperature of the rivet is raised sufficiently to explode the charge. This opens the end, and produces a strong internal head.

Machines for Riveting

Although hand-riveting is essential for certain work, there are many cases where machines can be used much more economically. Also, a machine-riveted joint is generally more satisfactory than one closed by hand. There are numerous different makes of riveting machine, one of the more simple type being shown in Fig. 40. This is a hydro-pneumatic squeeze-riveter, arranged for bench use and controlled from a foot lever. Pressure on this causes the upper tool to descend and close the rivet. The operator has both hands free to hold the work, and the same pressure is applied to each rivet.

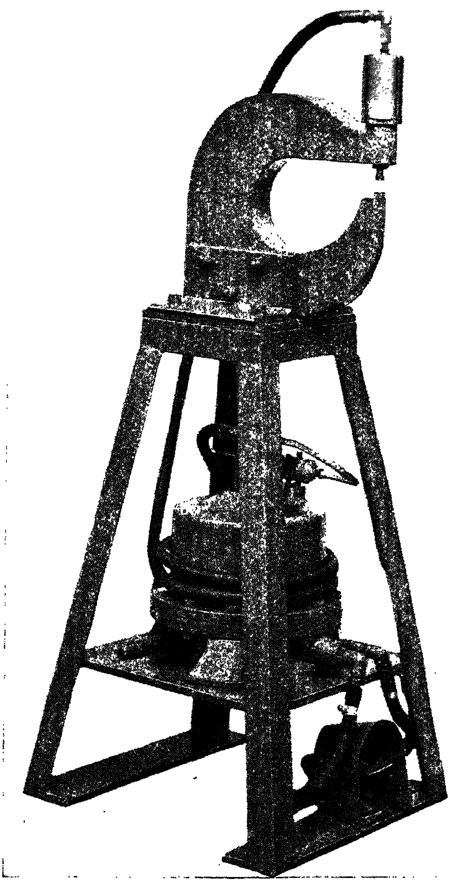


Fig. 40.—A "BROOMWADE" HYDRO-PNEUMATIC SQUEEZE-RIVETER DESIGNED FOR AIRCRAFT WORK

The Erco automatic punching and riveting machine (Fig. 41) is of entirely different design and operation to that mentioned above. This machine, which automatically punches a hole, inserts the rivet, and closes the head, can be used for both solid and tubular rivets. The hole is punched through two or more layers of material, the punch remaining in the hole to prevent movement of the sheets. This is pushed out as the rivet enters the hole.

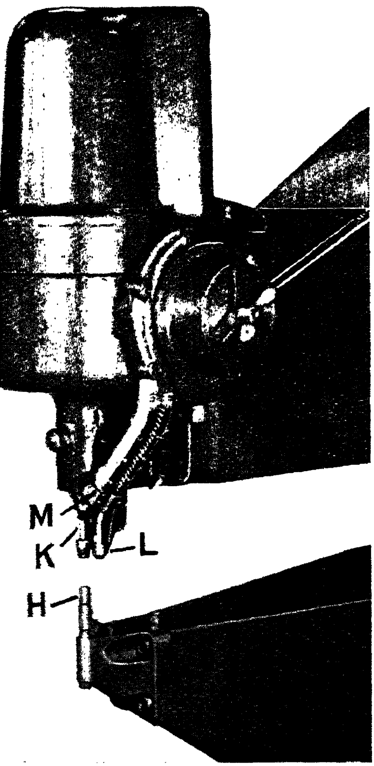


Fig. 41.—The head and anvil of the Erco aircraft riveting machine. (*A. C. Wickman, Ltd.*)

The complete automatic cycle is briefly as follows :

First, upon depressing the left foot-pedal, the punch is raised to the punching position in the anvil situated below *H*, and the shifter arm, carrying the die (*K*) swings to accurately align with the centre line of the punch. This releases an air valve, whereupon air enters the cylinder, forcing the piston and the piston-rod extension above *K* down on to the die (*K*). The descent continues, carrying the die down on to the work, depressing the stripper (*H*) and forcing the punch through the layers of metal. Releasing the foot pedal causes the piston to return to the top of the cylinder.

Then upon depressing the right-foot pedal, the shifter arm, carrying the rivet shoe (*L*), is accurately aligned with the centre line of the punch. This again releases the air valve, air enters the cylinder and the piston-rod extension descends, contacting the rivet shoe (*L*), carrying it down until it centres on the punch which projects slightly through the work.

The rivet shoe stops before touching the work, but the piston continues downward, pushing the rivet, which is held in the spring-closed split die shoe, through the die shoe on to the punch and on through the hole.

At the time the rivet shoe (*L*) is indexed, the punch lift is also withdrawn so that the punch can drop as soon as it is pushed out of the hole, thus making room for the rivet head which is formed by the further descent of the piston. The piston is finally halted by a positive stop, set to give the desired height of rivet head.

The rivet feed mechanism is a standard long-proven device. Rivets are poured into the hopper at the top, the drum tumbles them and passes only those with heads all pointing in the same direction to the chute. At the bottom of the chute, the slide *M*, synchronised with the balance of the automatic cycle, selects one rivet at a time which drops

through a tube into the rivet shoe (L) at the proper time.

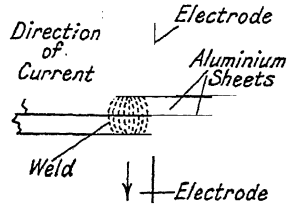


Fig. 42.—THE THEORY OF SPOT WELDING

Flush Riveting

Projecting rivet heads are highly undesirable on some external surfaces of an aeroplane, notably the wing, because of their additional wind resistance. In these positions rivets with countersunk heads are used. However, the material is too thin to allow countersinking by the ordinary methods, and so a process known as " dimpling " is employed. This consists of forcing down the metal around the hole to form the required countersink (Fig. 39E).

Several different methods are used in this country and abroad. Usually, the hole is drilled first, and then the " dimple " produced on another machine by pressure from a tool provided with suitably tapered point. The rivet is then inserted and closed. In some cases, after the hole has been drilled, the rivet is inserted and forced down under pressure to produce its own " dimple," after which the rivet is closed. This latter method can be carried out on specially constructed automatic machines.

Welding

As already mentioned, riveting is extensively used for assembling both minor and major components. However, engineers realised long ago that this process is not, from a production point of view, an economic proposition. It must be remembered that in addition to the actual riveting, the holes must be marked out (or expensive drill jigs employed), drilled, and the ragged edges cleaned. Considerable weakness is produced by the holes and to compensate for this loss of strength extra material must be allowed at the joints. This, together with the weight of the rivets, is a serious factor in aircraft design, where every effort is made to reduce weight to the very minimum.

The obvious solution to this problem lies in the use of electric welding. Unfortunately, aircraft engineers are considerably prejudiced against this process, due to the very unsatisfactory results obtained some ten or twelve years ago, when all-metal aircraft was becoming established. However, as the result of research work the design of welding machines has been considerably improved, and the process is now generally accepted for aircraft work, in this country as well as abroad. There is every indication that welding will be also used more extensively in this country on un-stressed parts. The properties of the metals used for aircraft construction are entirely different from those of iron and steel, and require entirely different treatment.

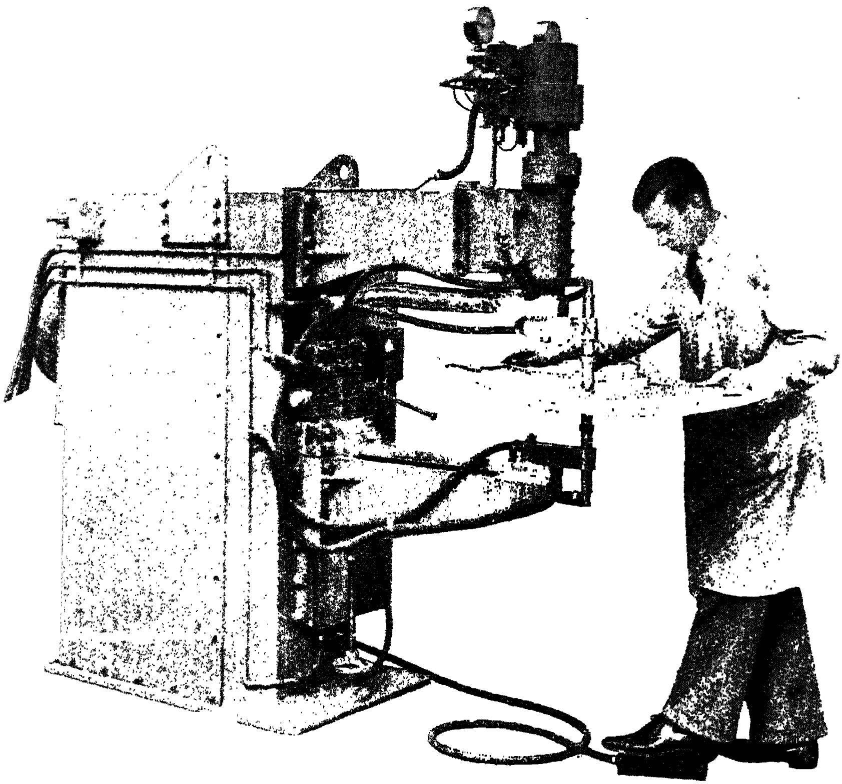


Fig. 43.—SCIAKY AIR-OPERATED SPOT-WELDING MACHINE BEING USED FOR WELDING STIFFENERS TO A PANEL

Spot Welding

The welding process is that known as electric resistance welding, or "spot welding," which operates on the principle that, due to the resistance offered by the metal, heat is produced when an electric current is passed through a conductor. If the metal is a good conductor, such as copper, very little heat is produced. On the other hand, iron and steel offer considerably more resistance and thus show a greater rise in temperature. Thus, if a very heavy current is passed through the metal sufficient heat can be produced to actually melt it. The practical application of this can be seen from Fig. 42, which shows two pieces of metal between the copper electrodes of a welding machine. At the point where the current passes through the metal, i.e. between the electrodes, the metal is melted.

By means of compressed air or hydraulic pressure, the electrodes nip

the sheets together during welding, and squeeze the melted areas into a solid piece. The weld thus produced can be seen, in the case of iron and steel, as a small blue spot. The time during which the current flows is very short, being only a fraction of a second, and should this be extended a large area of metal will be heated, part of which is liable to be burned instead of merely melted.

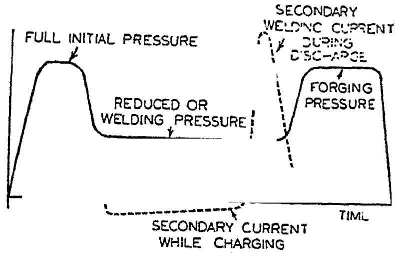


Fig. 44.—Diagram illustrating the Sciaky welding cycle

The full line represents the mechanical pressure of the electrodes, whilst the dotted line indicates the welding current.

In the case of light alloys, special difficulties are encountered. These metals are comparatively good conductors of electricity, and thus require a very heavy current, in the region of 6,000–7,000 volts, to produce sufficient heat to cause melting. Also, aircraft materials are usually heat-treated to obtain special physical properties, and excessive heat spoils these properties. Thus, the current must flow for a considerably shorter period than in the case of iron and steel to prevent damage to the internal structure. These remarks also apply to stainless steel.

Automatic Spot Welding

A machine specially developed for aircraft work is the Sciaky welder (Fig. 43), which incorporates several interesting features. The current is not merely suddenly released, and then cut off, but follows a special pre-determined cycle. When the operator presses a foot switch the electrodes come together and grip the work with considerable pressure, thus ensuring perfect contact between the pieces of sheet. The electrode pressure is then reduced, and the current flows for a fraction of a second. While the weld is still hot the electrode pressure is increased, this having a forging action on the plastic metal which is claimed to increase the strength of the weld. This cycle, illustrated diagrammatically in Fig. 44, operates automatically and continues repeatedly until the foot is removed from the switch.

On the head of the machine is a cylinder, operated by compressed air, which is responsible for the electrode pressure cycle. It will be seen that this machine is practically foolproof, as the operator has no control over the period of current flow or the electrode pressure. Adjustment can be made to vary the cycle to suit different metals or thicknesses. If the metal is very dirty or covered with paint, faulty welds are liable to be produced. However, mounted on the control panel are three lights, red, green, and white.

Should, for any reason, a weld be "burnt," the red bulb is illuminated and a hooter sounded. At the same time the machine automatically

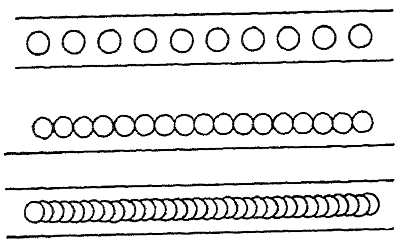


Fig. 45.—DIFFERENT TYPES OF SEAM WELDS OBTAINABLE BY VARYING THE RATE OF CURRENT INTERRUPTION AND SPEED OF THE WHEEL ELECTRODE

stops and can only be restarted by pressing a master switch. If sufficient current is not passed, and a weak weld produced, the green bulb is illuminated and the hooter sounded. The white bulb indicates the good welds. Each weld is automatically recorded on a chart, according to its colour (red, green, or white) and thus, with these safeguards, it is impossible for a faulty weld to escape detection.

Sometimes it is not practicable to take the work to the welding machine, as in the case of larger assemblies, and portable equipment must be used. Special attachments are available which can be connected to the electrodes of a Sciaky machine by flexible cables. This allows a light pair of " pinchers " to be taken to the work, this operating with the same variable pressure cycle mentioned before.

Seam Welding

Another type of welding machine makes use of a pair of copper rollers instead of the normal type of electrodes. These are adjustable through 360°, and are used for welding long seams. The upper wheel is rotated by mechanical means and thus the work is fed between the two wheels at a predetermined speed. By means of a Thyratron valve the current is interrupted up to 1,500 times a minute. Thus, as the work feeds through the rollers a series of welds are made and, by adjusting the speed of travel and the number of current interruptions, any desired weld spacing can be obtained (Fig. 45). This process is known as " seam " or " continuous " welding and allows parts to be welded at speeds up to 140 in. per minute. The speed can be varied by pressure on a foot lever.

Oxy-acetylene Welding

In addition to the use of the electric resistance process a considerable amount of light-alloy welding is done with oxy-acetylene equipment. This consists of melting the edges of the sheet and fusing them together, with the aid of a flame from a mixture of oxygen and acetylene gas. Melted with this is a rod of the same composition as the work. A flux is used to remove the film of oxide, which is liable to prevent the formation of a good weld, this being applied by dipping the end of the rod in the flux. Wherever possible the diameter of the rod should be approximately the same as the thickness of the sheets although, in the case of very thin work, this is not practicable.

Before commencing to weld it is important that the edges of the work should be free from every trace of dirt or grease. This can be done with

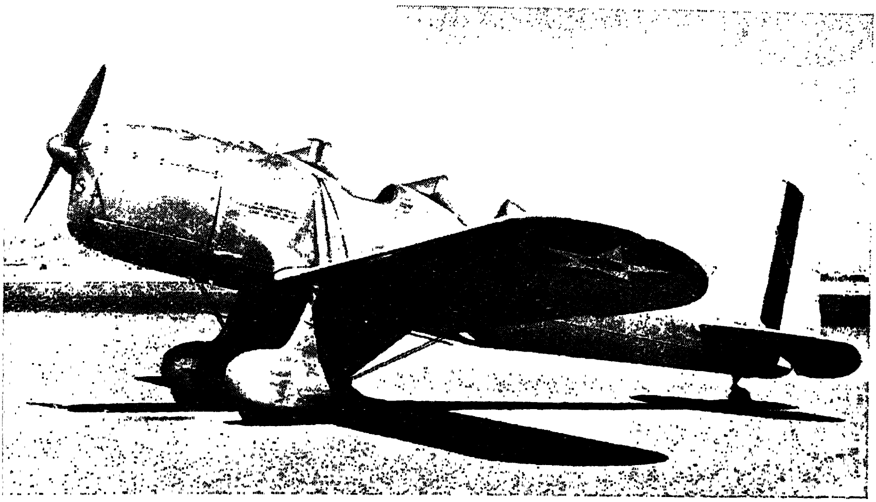


Fig. 46.—A Ryan XPT-16 low-wing metal-fuselaged training plane

This machine is powered with a 125-h.p. Manasco engine. Note the spats covering the wheels and legs. (*Ryan Aeronautical Co.*)

a wire brush or by the light application of emery cloth. After welding, all traces of flux must be removed by a thorough brushing in hot water. Apart from its use for light alloy components this form of welding is extensively used for assembling tubular steel fuselages. Some of these joints are very complicated and may include as many as seven or eight tubes. To ensure accurate location of the tubes in fuselages, engine mountings, and similar components extensive use is made of welding jigs.

Provision is made on these to locate the tubes in their relative positions, where they are lightly tack-welded together. After removal from

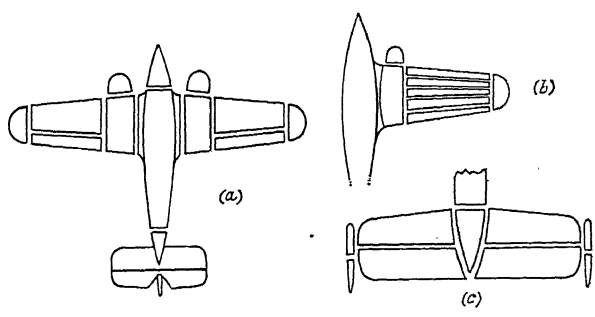


Fig. 47.—Unit construction

(*a*) One of the most common methods of sub-dividing a plane into units to enable easy production. These units are themselves often composed of smaller units. In some cases the tail unit is built as a single piece whilst in others it is split up into sub-assemblies.

(*b*) Unit construction as practised by certain American firms. The main plane is divided into five longitudinal units which are riveted together. The wing tip is then added.

(*c*) Method of splitting up the tail section of a large machine. At the sides are shown the fins and rudder.

the jig the joints are then fully welded. The jigs are usually built-up from very strong steel sections, in order to prevent distortion of the work due to heating. However, at the same time, the tubes must be free to expand and contract lengthways and considerable skill is necessary during welding to eliminate excessive distortion. After the first one or two components have been welded it is possible for the operator to determine the sequence in which the various joints must be dealt with so that distortion is reduced to the very minimum. Such importance is attached to the skill of the operators that the Air Ministry stipulate that welders engaged on aircraft work must pass stringent practical tests at regular intervals

Chapter IV

ASSEMBLY

HAVING dealt with the various workshop processes, we can pass on to the application of these in actual practice. The modern tendency in aircraft design and production is towards "unit construction." This means that the machine is composed of a number of units or assemblies, bolted together to make the complete plane (Fig. 47). These units usually consist of the wings, fuselage, tail portion, engines, and undercarriage which, in turn, are sub-divided into smaller units. Thus, it is possible to make these in separate departments or even factories, and bolt them together in one assembly department.

Unit Construction

In order to secure the accuracy and uniformity which this entails extensive use is made of jigs. When the first component from each jig, or set of jigs, has been successfully assembled, it can then be taken for granted that every other part made from the same jigs will also go together correctly.

This feature has another important advantage. An aeroplane is comparatively small and, consequently, the number of men who can work on it at the same time is very limited. However, by making the various units in separate departments, away from the fuselage, a considerably larger number of men can work simultaneously on the one machine, thereby increasing the output. Throughout the following pages it must be remembered that countless different types of aeroplanes are in existence, each embodying different features of design. Consequently, it is only possible to deal with this side of production in a very general manner.

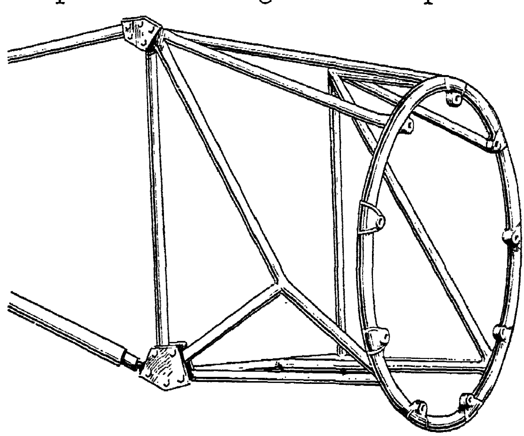
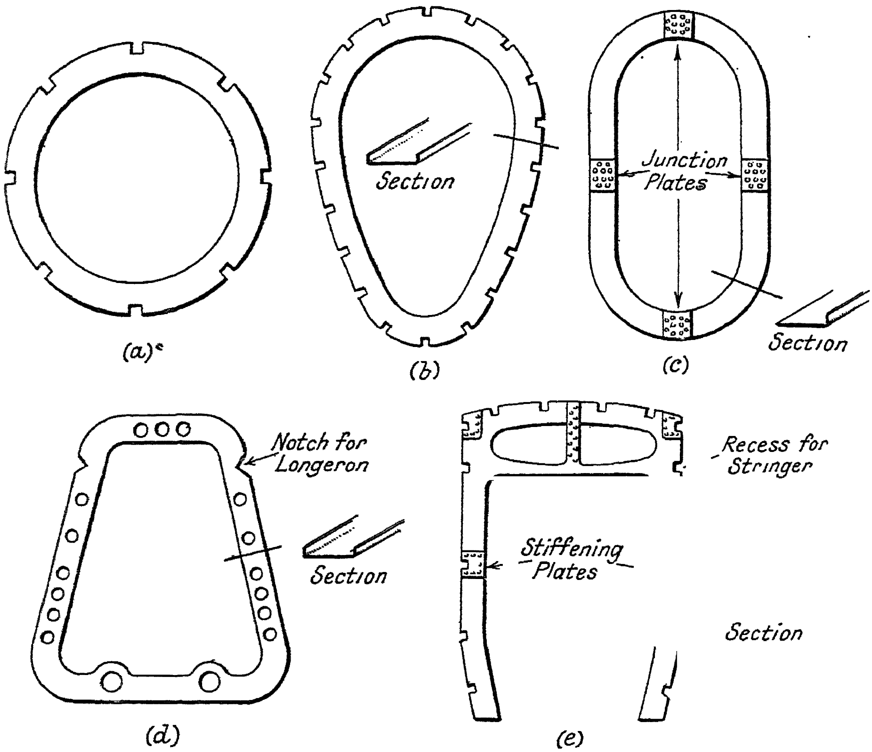
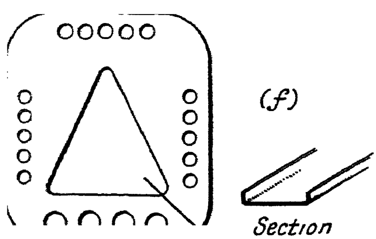


Fig. 48.—A TYPICAL MOUNTING FOR A RADIAL-TYPE ENGINE

This is built up from welded steel tubes, provision being made to attach the engine with nine bolts.





Figs. 49–51.—FUSELAGE FORMERS OR RINGS

Most of these are made from pressings, and have a channel-shape cross-section. Some rings are in a single piece whilst others are made from several pieces riveted together, as in (*c*). In (*f*) is shown a bulkhead separating the tail unit from the fuselage. This is little more than a strong former.

Engine Mountings

In the case of single-engine machines the fuselage can be roughly divided into three sections, i.e. the nose, cabin or cockpit, and the rear. In the nose is housed the engine, fastened to an "engine mounting" which, in turn, is attached to the fuselage. As a rule, the mounting consists of a welded steel-tube frame, designed to combine strength, rigidity, and lightness. Considerable care is necessary when making this structure as, in the event of a bad landing, it is called upon to withstand very heavy stresses, due to its overhanging design. Also, it is subject to considerable

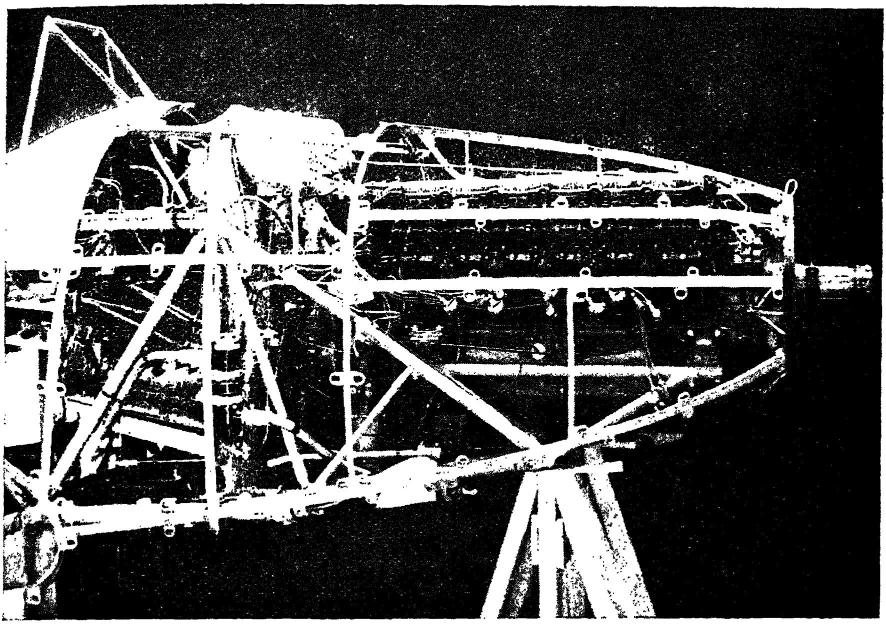


Fig. 52.—SHOWING THE ENGINE AFTER BOLTING TO THE MOUNTING

It will be seen that a framework has been built around the engine for attachment of the cowling. (*Fairey Aviation Co. Ltd.*)

vibration from the engine, although this is reduced to some extent by the use of rubber blocks, bushes, and washers.

Mountings for radial engines terminate in some form of ring, to which the engine is bolted (Fig. 48). An internal tubular frame takes the load of the engine, whilst four or five straight or circular pieces are arranged outside this to hold the cowling. The cowling is a circular sheet-metal covering protecting the engine, and is designed so that it can be easily removed to give access to the interior. The mounting is secured to the fuselage by bolts, usually four.

In-line engines rest on a horizontal "bed" type mounting (Fig. 52) of an entirely different type to that used for the radial engine. For this, also, the construction consists of a welded tubular framework, although in some cases the tubes have been replaced by a girder structure built from extruded angle-sections. Examination of the sketches will show that some of the joints are very complicated. These are welded with oxy-acetylene equipment.

Fuselage Rings

The cockpit and rear portion form the fuselage proper and consist of a single structure. Many types of fuselage are used in aircraft through-

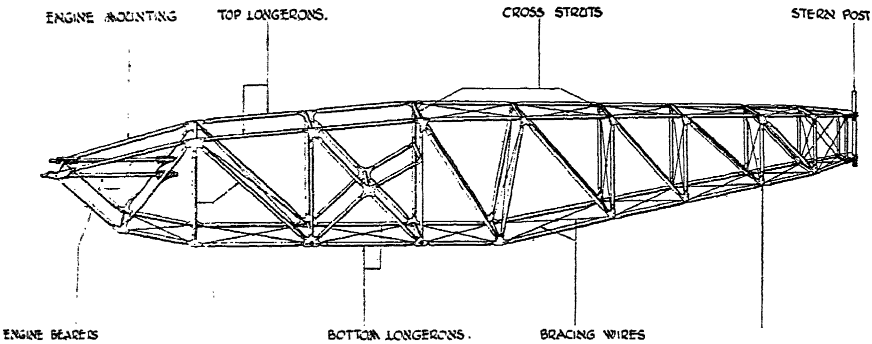


Fig. 53.—THE FUSELAGE OF AN ENGLISH TWO-SEATER BIPLANE CONSTRUCTED FROM TUBES

In this case welding has been avoided by using plates provided with sockets to receive the ends of the tubes. In most other countries the joints would be made by welding the tubes together in a jig.

out the world, two of which can be seen in Figs. 54 and 65. These are very simple and consist essentially of a number of circular or elliptical rings held together by straight spars. Special names are given to the various airframe parts. The rings mentioned above are often known as "formers," from the fact that they are responsible for the form or shape of the fuselage. Very few, if any, rings in a fuselage are identical, due to the tapering external contours of the machine. "Stringers" is the name used for the straight pieces joining together the formers, whilst "longerons" are comparatively stout girders running lengthways down the fuselage.

Dividing the engine and mounting from the cockpit is a partition or "bulkhead," another bulkhead separating the cockpit from the rear or tail portion of the fuselage. These are solid rings made from sheet material. The actual details of fuselage formers varies with every different type of plane, but they nearly all consist of some variation of the shapes in Figs. 49–51. In some instances they are made from several curved lengths of channel formed to shape on a press from flat strip. These are very rigid and provide considerable strength.

Another common type is built from fairly wide strips of material flanged over at the edges to provide strength. Recesses are notched out to provide clearance for the stringers. This particular fuselage (Fig. 50E) is composed of two comparatively straight side pieces joined at the top and bottom by curved pieces. Riveted to the top is a cross bar and vertical piece to provide extra strength. Different fuselage construction, used in some continental aircraft, is built up from panels internally braced by girders and spot welded.

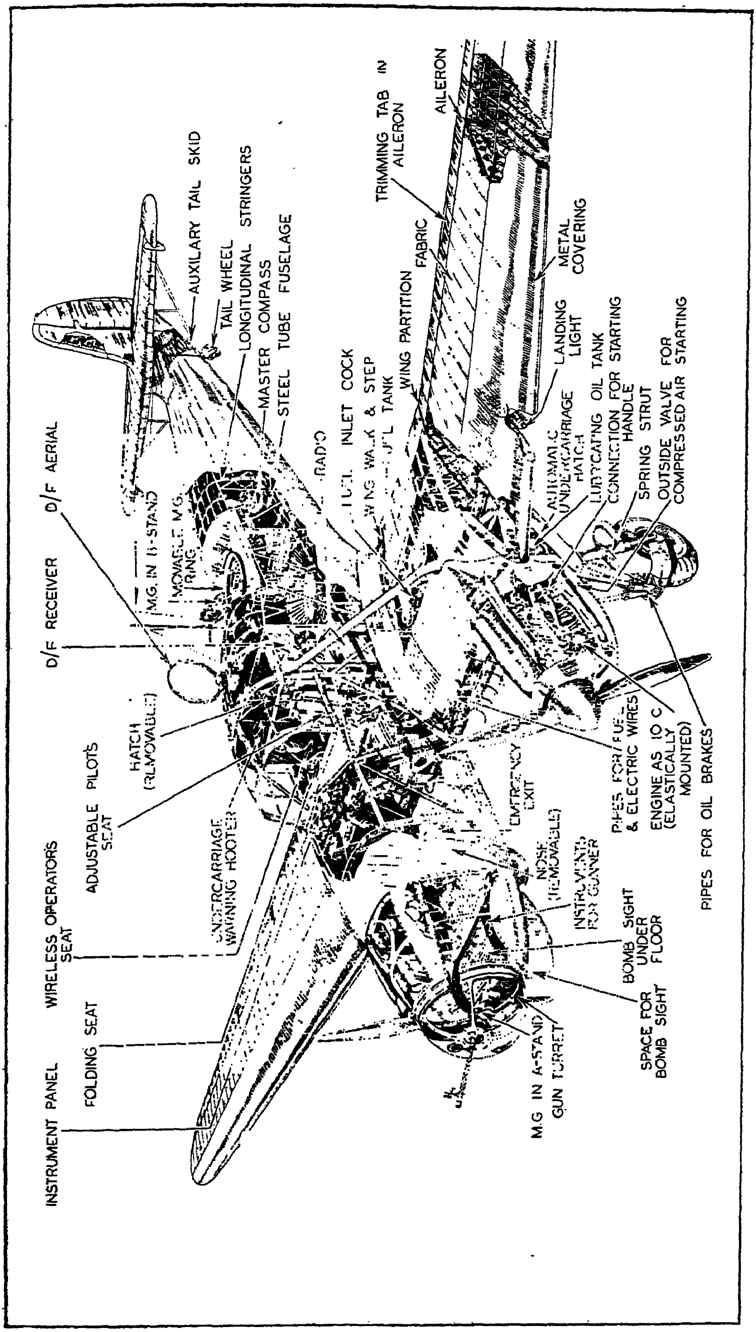


Fig. 54.—DETAILS OF THE CONSTRUCTION AND EQUIPMENT OF A FOREIGN-MADE AEROPLANE

Fig. 55.—The interior of a French wing panel constructed entirely by welding duralumin sheet and stiffeners

Parts of the girder segments are of box section, with lightening holes in one face. This latter face is made separately from a flat strip, the holes being pressed out and the edges flanged for strength. The remaining part of the girder is produced as a single piece, and the above strip is fastened to it by spot welding. The outer formers to which the skin or covering is attached are made from a shallow channel pressed from strip. Flanged lightening holes are also pressed in at the same time on a rubber press. The stringers, of flanged U shape, are made from lengths of flat strip, formed either on a press brake or by drawing. These support the skin, to which they are attached by spot welding, and also position the girders. Additional strength is provided at the corners by welding curved sheets to the structure. For the sake of lightness these also are liberally provided with holes.

Tubular Construction

Considerable use is made abroad of fuselages constructed from steel tubes welded to form a rigid framework (Fig. 53). In this country, however, this design is not so popular. Very skilful welding is required, as some of the joints are exceptionally complicated. Jigs are used to locate the various members in their correct positions and special precautions are taken to counteract the effects of contraction and expansion. In its most simple form this type of fuselage consists of longerons suitably braced together. Tail units and wings are also built up from steel tubes.

Fuselage Assembly

In general, the following procedure is followed when assembling a fuselage. The frames and bulkheads are arranged vertically in a jig which locates them the correct distance apart and at their relative heights.

This jig may be a rigid framework of wooden or steel joists provided with a few locating holes to which the rings can be temporarily secured by bolts. The stringers are next placed into position and riveted to the frames by portable or hand equipment. Window and door frames are then added and secured in a temporary manner with bolts.

Following the addition of keel plates the assembly is ready for the skin. This consists of comparatively small sheets cut to shape on a guillotine. It will be realised that the constantly changing contour of the machine prevents the use of very large sheets. Rivet holes are drilled in the frames and stringers during manufacture and, during assembly, these are used as drilling templates for the skin. The sheets are held in position by light clamps or locating pins and the holes are drilled from inside the fuselage, through those already present.

Portable electric or pneumatic drills are used for the purpose. The window and door frames are now permanently riveted to the skin. After this much of the equipment, such as electrical and hydraulic controls, etc., can be added. It will be noticed that the cockpit, wings, tail section, and engine are not yet attached. These are usually complete and separate units, which only require bolting to the fuselage.

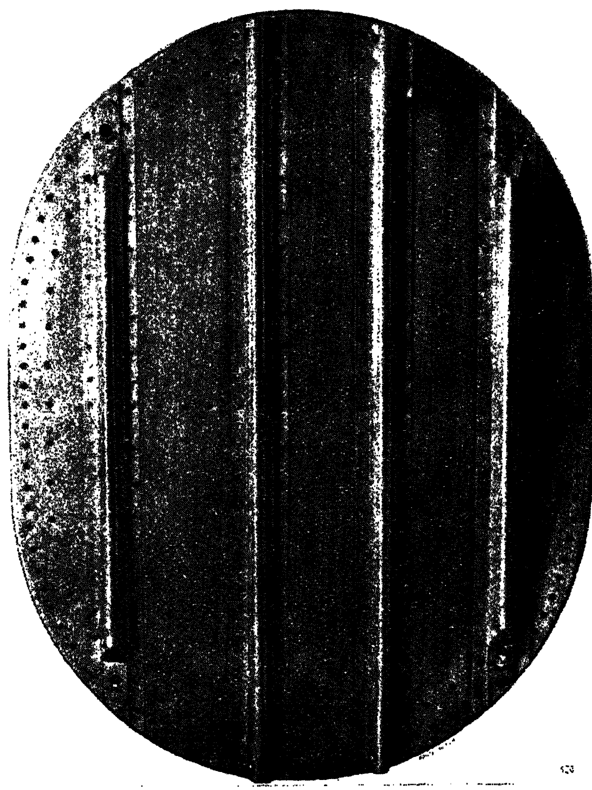


Fig. 56.—A panel for a French machine built up by welding stiffeners to stainless steel sheet by the Sciaky process

Wing Spars

There are many types of wings, a few of which are shown in Fig. 57. From these it will be observed that

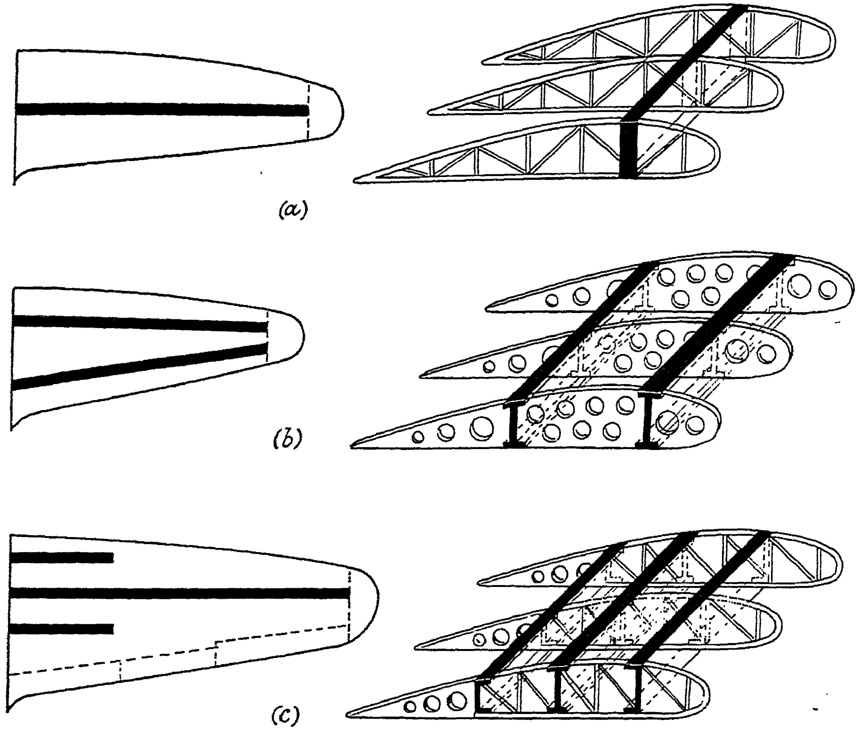


Fig. 57.—Three Types of Wing Design

(*a*) A single-spar wing, (*b*) a two-spar wing, and (*c*) a three-spar wing as used on large air liners. This diagram does not show the method of attaching the various rib parts to the spars or the actual construction of the ribs and spars.

they all consist of a number of ribs strongly braced together to form a rigid unit, and then covered with skin. Inside are carried the fuel tanks. Running practically the full length of each wing are one or more spars, to which the formers or ribs are attached. These are called on to take a considerable load during flight, and consequently are of very strong construction.

The more simple form of wing spar may consist solely of a single length of extruded section (Fig. 58) specially designed for strength. On the other hand, it may be built up from extruded angle sections riveted to sheet in a similar manner to the girders used for bridge building. For the sake of lightness considerable use is made of the built-up lattice type of spar, which also closely resembles the design employed for structional engineering work. Two extruded angle sections are riveted together and joined to a similar pair by some form or other of bracing, thus making a beam or spar of considerable strength. This design is more satisfactory

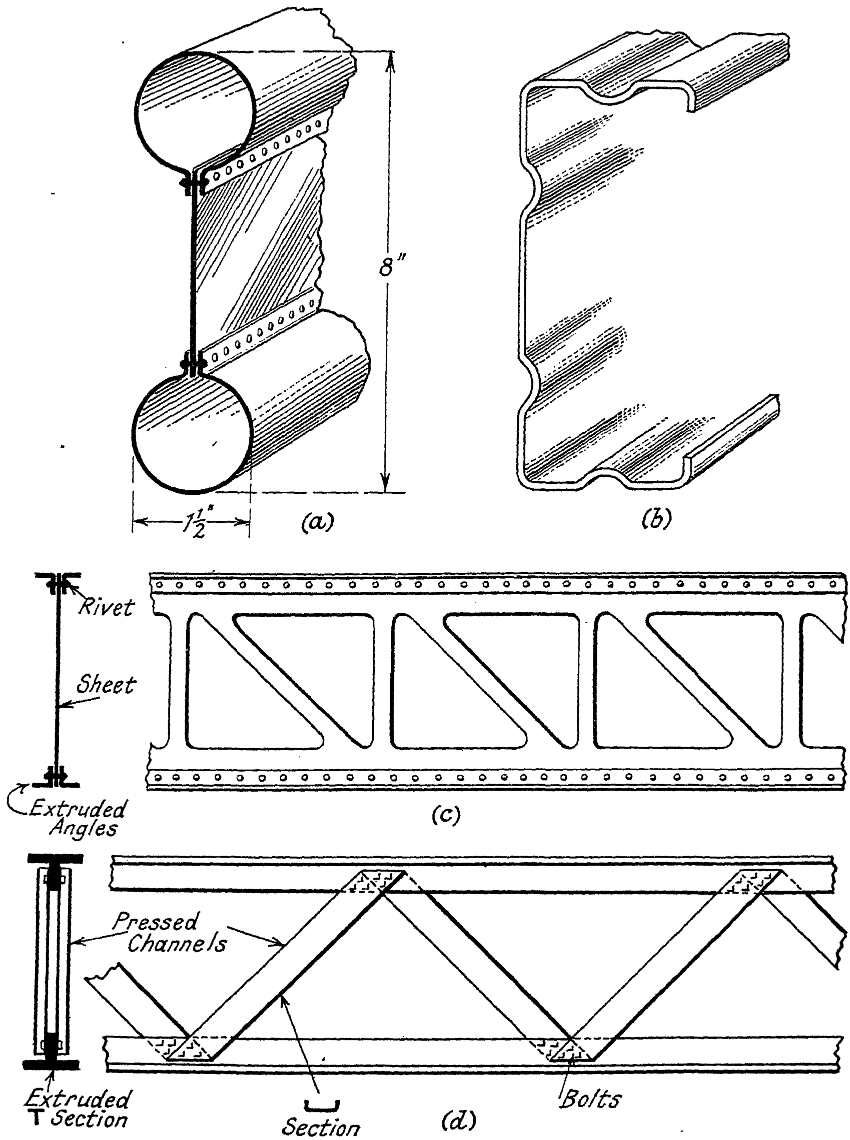


Fig. 58.—A FEW OF THE NUMEROUS TYPES OF WING SPARS

(*a*) Two steel tubes, split and provided with suitable flanges, are riveted to a long narrow plate.

(*b*) This spar is produced on a press brake from a sheet of flat material.

(*c*) End and front views of a spar resembling very closely in design the ordinary beam used for structural engineering work. This consists of extruded angle pieces riveted to a plate which has been provided with lightening holes.

(*d*) An economical, but equally efficient, version of the spar in (*c*). This is built from two extruded tee sections joined by channel pieces.

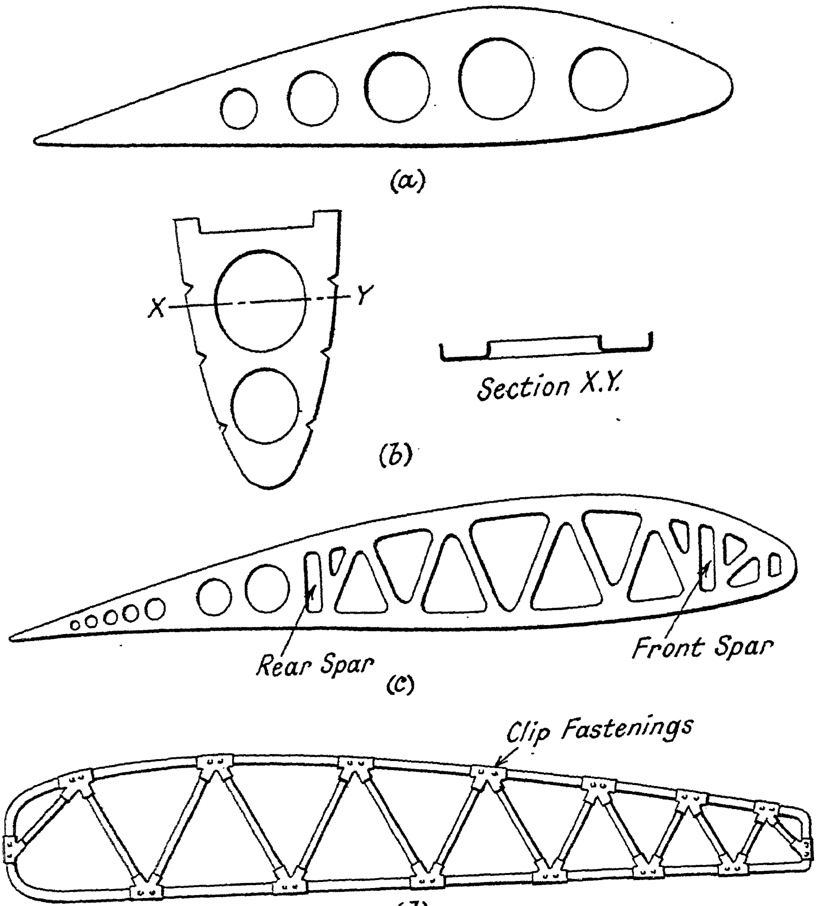


Fig. 59.—TYPICAL WING RIBS

The first three are pressings and (*d*) is a centre-section rib composed of dural tubes held together with special clip fastenings.

than that in Fig. 58*c*, which necessitates considerable wastage of material by cutting holes from the solid sheet.

Ribs

Two main types of wing ribs are in common use, one of which is produced by pressing. Pressed ribs can be produced more quickly than the other type, which is composed of a number of pieces welded or riveted together, and is also stronger. A group of such ribs is shown in Fig. 59. These mostly consist of a single piece of metal with the edges flanged over for attachment of the skin by riveting. A considerable amount

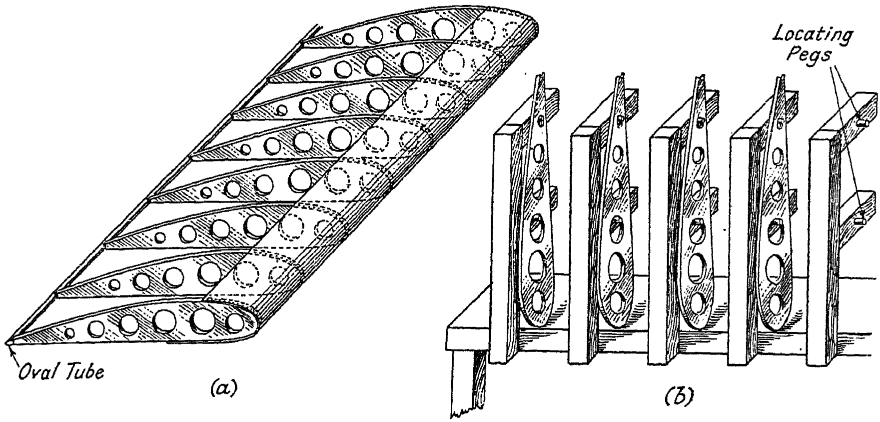


Fig. 60.—Aileron construction is comparatively simple, consisting of ribs attached to a spar

The outer ends are recessed to suit an oval tube to which they are secured with rivets. In (*b*) is shown one common type of aileron assembly jig.

of the material is removed for lightness, and the edge of the remaining metal is flanged to provide extra strength.

The shape varies according to the position and function after assembly, and the rib may be composed of either one, two, or three pieces. Built-up ribs are made by welding or riveting together tubes or pieces of material drawn to a square, tee, or other special shape.

Aileron

The aileron is constructed in a somewhat similar manner to the wing, being made up from a number of ribs attached to a spar, and covered with either sheet metal or fabric. As this component is subject to torsion loads the spar is either of tubular design or similar to that in Fig. 60. This is a semicircular channel to which the ribs are riveted. As in the case of wings, the ribs may be built by welding together tubes or other sections.

The semicircular channel is formed to shape on a press brake from a length of flat strip, the ribs then being inserted, the holes drilled, and the assembly riveted together. On some machines the rear portion of the wing adjacent to the aileron is provided with a curved recess or " shroud " inside which the curved portion of the aileron channel moves. This shroud is usually also shaped on a press brake.

A very similar design is adopted for the flaps, elevator, tail plane, rudder, and wing tips, these being constructed from ribs or formers covered with metal or fabric.

Fig. 61.—A 430/450-H.P., 9-CYLINDER, AIR-COOLED RADIAL ENGINE

This is a neat, compact unit, enclosed in cowling.

Assembly

The aileron assembly jig is very simple, and the same principle is also applied to jigs for certain other similar parts. Accurate spacing of the ribs is the main function of this, and thus the jig consists of a number of upright supports, one for each rib, spaced to suit the finished aileron. Two arms project at right angles to each upright, these having a pin which fits into either a small hole specially drilled in the rib, or into one of the lightening holes. Consequently, if the ribs are all hung on their respective arms, they will be in the exact position which they will occupy in the completed aileron.

Each one is correctly spaced from its neighbour and held vertically. After riveting together the ribs and channel, a slight movement to the right releases the whole assembly from the fixture. Finally, the skin is added.

Engine Units

Engines are built as self-contained units, held to their mounting by a few bolts and the complete engine can be installed in one to two hours. Surrounding the radial type is a protective cowling (Fig. 61) which varies slightly in shape according to the engine design. In some cases it is possible to produce the cowling as a spinning, whilst the irregular shape of

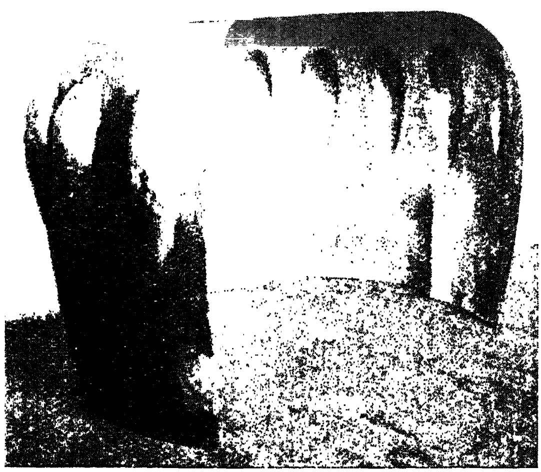
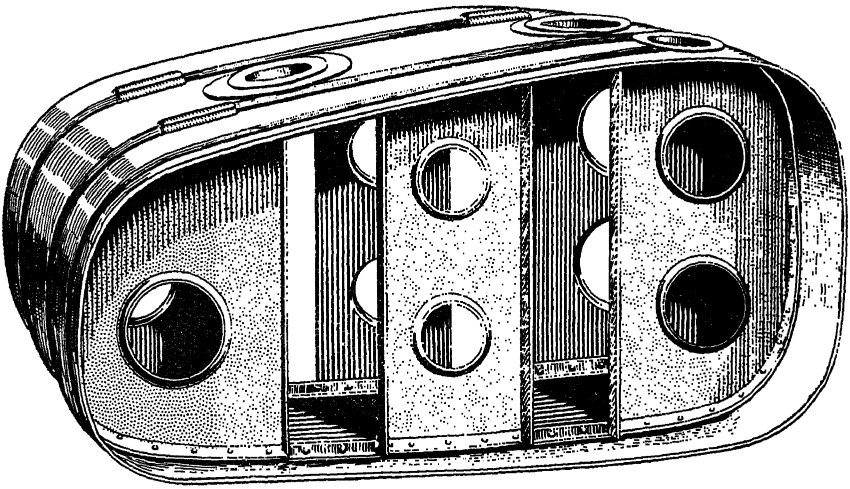
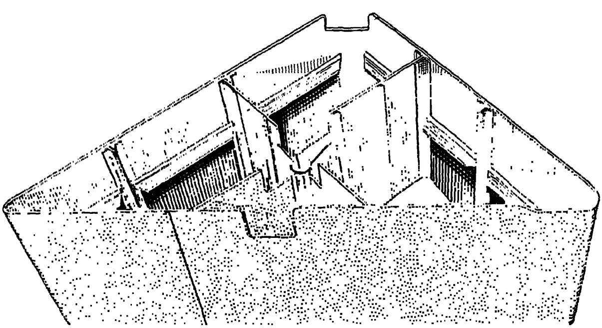


Fig. 62.—PART OF AN ENGINE COWLING MADE FROM AM503 ELEKTRON ALLOY. (*F. A. Hughes & Co. Ltd.*)



(a)



(b)

Fig. 63.—Two types of fuel tanks with the ends removed to show the arrangement of the baffle plates

(*a*) is a riveted Elektron tank of English design, whilst (*b*) is a welded duralumin tank for a French machine. (*Courtesy of F. A. Hughes & Co. and Sciaky Ltd.*)

others make essential the employment of wheeling machines and panel beating. An example of this is seen in Fig. 62, where it is necessary to beat out the " blisters " by hand. Sections of cowling can also be made by pressing and stamping operations.

Towards the rear of the unit in Fig. 61 can be seen the cooling gills, in their open position. These are controlled from the cockpit and are operated by a system of accurate gears and screws arranged around the interior of the cowling. The " spinner " protecting the nose of the air-screw is a typical example of the work which can be produced by spinning in a lathe.

Fuel Tanks

Tanks for fuel storage are generally carried inside the wings. In the case of biplanes the upper wing is used, so that the petrol can be gravity-

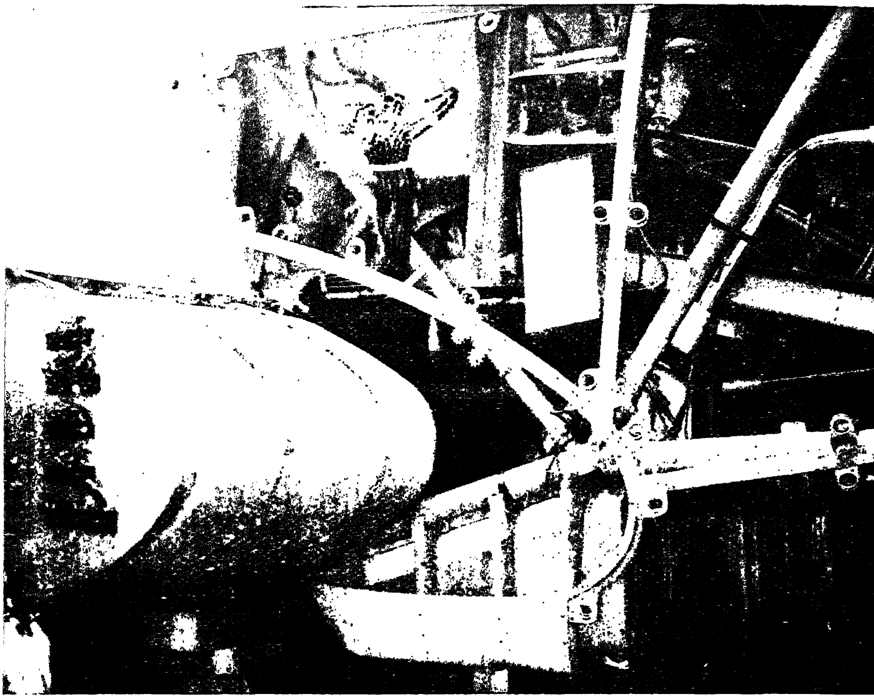


Fig. 64.—An oil tank fitted at the junction of the wing and fuselage

To the right can be seen part of the tubular cockpit framework. (*Fairey Aviation Co. Ltd.*)

fed to the engine. The tanks are neatly fitted between the spars and vary in appearance according to the type of machine into which they are to be fitted. In order to distribute the weight as evenly as possible they are usually suspended in closely fitting slings of wide steel strip.

The exterior or shell is shaped to suit the position into which it is to fit, and may be either plain or provided with stiffening ribs. Most of this work is done by ordinary panel-beating methods. Inside the shell are several baffles which prevent uneven movement of the liquid during flight, and also provide additional strength to the tank (Fig. 63). At the same time, however, the petrol can pass freely from one compartment to another through large lightening holes. The ends of the tank are slightly curved and are provided with a flange to enable fastening to the shell. It is now common practice to make tank ends from pressings. Certain fittings are added, such as an outlet, gauges, filler, vent pipe, etc.

A wide variety of sheet materials are used for fuel tanks, including copper, brass, steel (tinned), duralumin, aluminium, and elektron. The method of assembly varies according to the material. For example, for

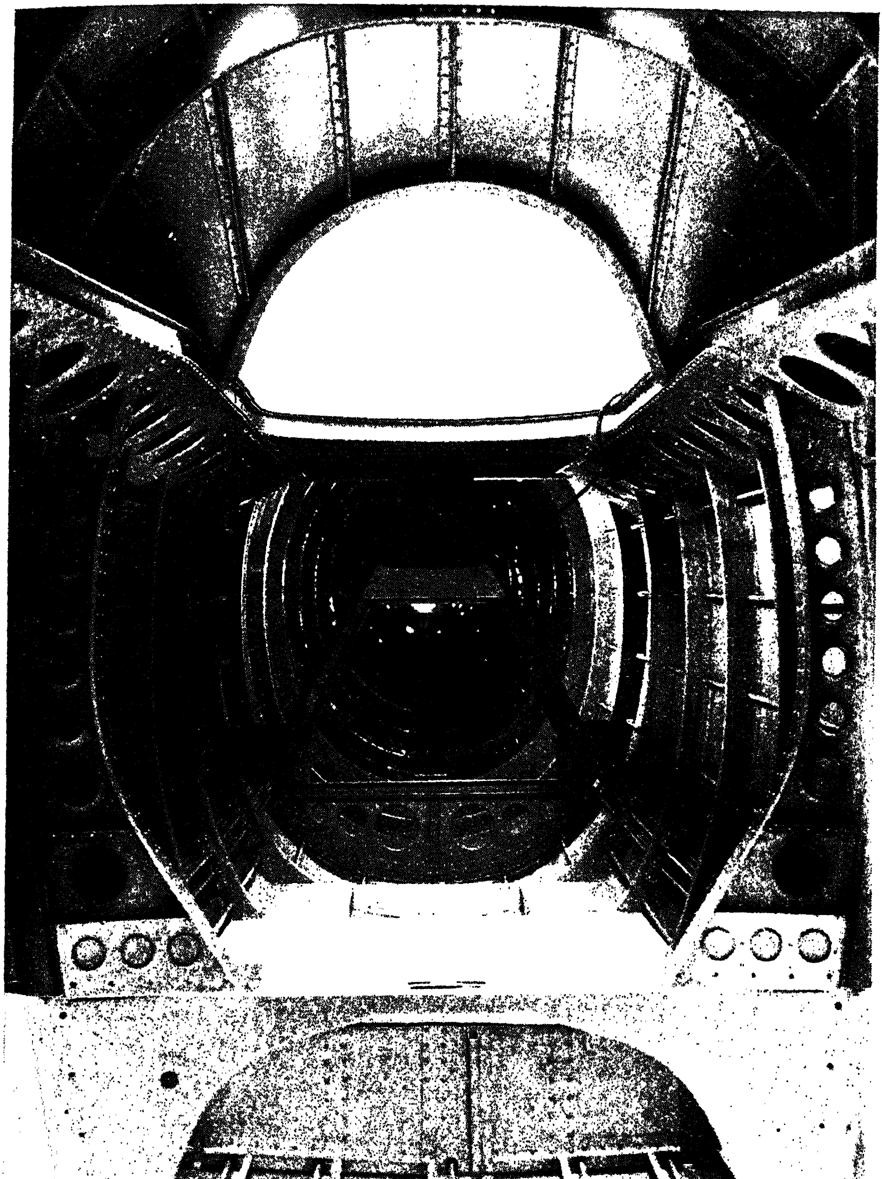


Fig. 65.—The interior of a modern metal fuselage

This view clearly illustrates the strong construction provided by the rings and stringers. (*Fairey Aviation Co. Ltd.*)

Fig. 66.—A PARTLY ASSEMBLED FUSELAGE, SHOWING THE ARRANGEMENT OF THE RINGS AND STRINGERS

After completion the centre pole and the wood locating arms are withdrawn. (*Fairey Aviation Co. Ltd.*)

elektron and aluminium welded joints are used, whilst for duralumin they are riveted. Wrapped joints are employed for steel construction, these being sweated and riveted. Tanks welded by the electric resistance process are also in use.

All-metal Fuselage

Fig. 65 shows the interior of a well-known military aircraft. The fuselage consists of more than twenty formers or rings, joined by four longerons. Instead of using stringers for stiffening the fuselage in the longitudinal direction, one edge of each " plate " used for covering the exterior is curled on a press brake, thereby achieving a similar strengthening effect.

The rings are blanked-out on a press and then formed to shape on a hydraulic press, whilst the skin plates are cut to shape on a guillotine and the edges curled on a press brake. Each ring is slightly different in size and design, according to its position and the stress it is required to withstand.

A fuselage assembly jig is seen in Fig. 66. This consists of a long central pole, to which are bolted a series of wooden frames, one for each ring. These have screwed to their ends a pad of wood which locates inside the channel of the ring. In this manner the rings are located in position until the longerons are attached to form a rigid skeleton. Certain flooring is next added to the front end, after which the exterior is covered with the 5-in. wide plating or skin.

When first applied the plates are temporarily held in position by a

few bolts, known as "service bolts," which pass through certain holes already drilled in the rings. The rivet holes are drilled in the plates before coming to this assembly jig and, using these as templates, the remaining holes in the rings and longerons are drilled with portable equipment. This is the reverse method to that mentioned earlier. Following this the plates are removed for anodising and painting, and are then riveted to the fuselage. After completion the wooden locating frames are unbolted and withdrawn from the interior. A more recent type of jig is provided with collapsible metal arms, instead of wooden frames, which can be swung inwards when the jig is removed.

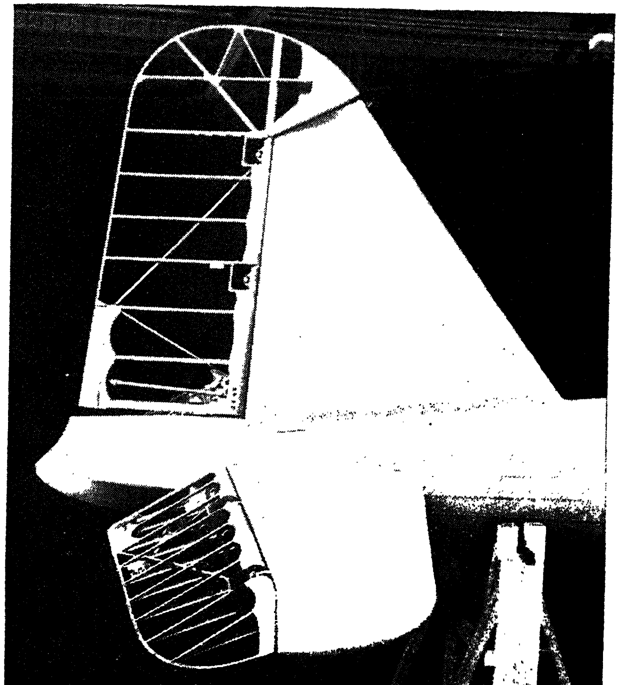


Fig. 67.—A METAL TAIL UNIT SHOWING THE DESIGN OF THE RUDDER AND ELEVATOR.

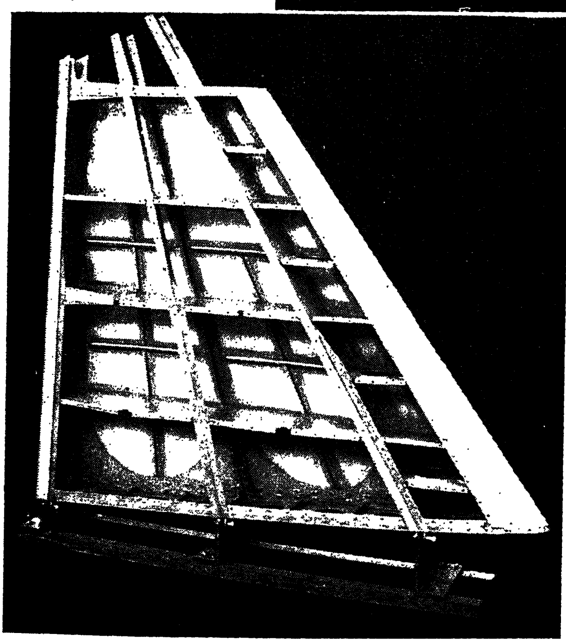


Fig. 68 (*below*).—THE INTERIOR OF THE STERN POST OF THE TAIL UNIT IN FIG. 67. (*Fairey Aviation Co. Ltd.*)

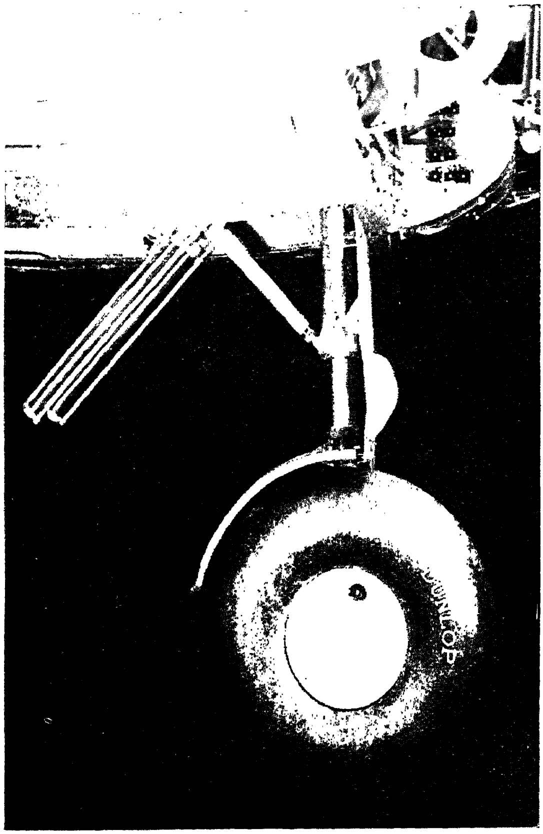


Fig. 69.—PART OF A RETRACTABLE UNDERCARRIAGE

The manufacture of this equipment requires very fine and accurate machine work. (*Fairey Aviation Co. Ltd.*)

Tail Unit

In Fig. 67 is the tail unit for this same machine. The three hinged portions are very similar in construction to an aileron, and are built up from pressed ribs of various designs, attached at one end to a semicircular channel. All parts are jig-built, and afterwards covered with fabric. The fin is also constructed from pressed formers, riveted to duralumin spars, and then covered with metal skin.

A partly completed fin is shown in Fig. 68. The various formers and spars have been riveted together to form the framework, and the nose piece then added. Skin has been riveted to one side and the fin is seen awaiting the attachment of the other side. It will be seen that stiffeners have been riveted to the interior of the skin to provide additional strength. The nose piece has been shaped on a folding press.

Wing Fillets

The wing fillet is the portion where the wing joins the fuselage, and the shape of this is very complicated. Formerly, this part was always produced by panel beating, but it is now quite common practice to either stamp or press it. Another sheet-metal component of complicated shape is the spat encasing the wheel and leg of some machines (Fig. 46).

Chapter V

WOODEN AIRCRAFT

ALTHOUGH the all-metal aircraft plays such a prominent part in the modern world of aviation, machines of wood construction are still built in comparatively large quantities for both military and commercial use. The general design of the various parts is very similar in many respects to that of the corresponding metal components. Certain items, such as ailerons and flaps, are often made from light-metal ribs covered with either fabric or sheet metal.

Ribs

Two types of wooden wing ribs are shown in Fig. 70. One consists of a nose rib made from a single thickness of plywood, to which is glued a wider strip of thin wood to facilitate attachment of the skin, and also provide additional strength (Fig. 70 *c*.). For the sake of lightness, much of the interior is removed.

Entirely different construction is employed for the other rib. A framework of small pieces (*b*) is first glued together, and then covered on both sides by thin plywood, this forming a light but very strong rib. The ribs are attached to the spars by glue, wooden blocks, and small aluminium clips. Spruce is chiefly used for this work.

Wing Spars

Wing spars can be made in a rather similar manner to the rib in (*b*). A wooden frame is built up by glueing together a number of thin wood strips, and the sides are covered with thick plywood (*a*). It will be appreciated that considerably stronger results are obtained by building up the various parts from laminations than would be provided by single pieces of thicker wood. The laminations for the two booms (or long beams) consist of strips of spruce 4–5 in. wide and approximately $\frac{1}{2}$ in. thick. In many cases it is not possible to use single-piece strips, as the spars are often 50–60 ft. in length, and so a number of shorter pieces, scarf-jointed and glued together, are employed.

After the laminations have been glued to form the boom the sides are trued on a spindling machine. Following this the internal bracing pieces, previously made in a similar manner, are placed in position and glued between the two booms, as in (*a*). This work is done in jigs provided with clamps which are tightened to hold the assembly under firm pressure until the glue is set. A somewhat similar procedure is employed for all glueing operations, as it is essential that the various parts be held together

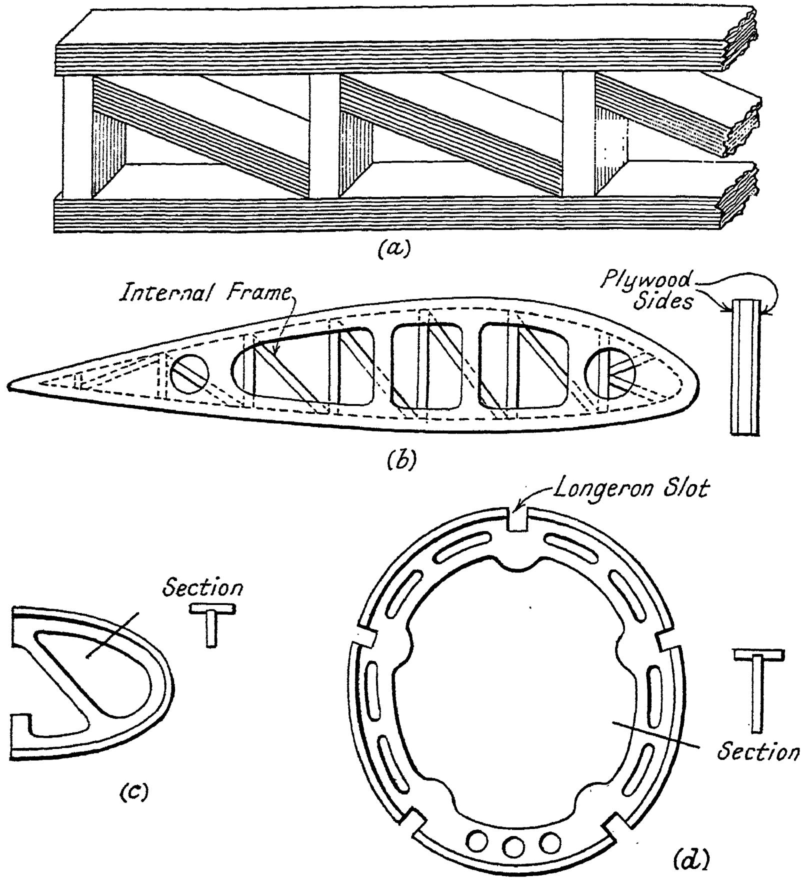


Fig. 70.—EXAMPLES OF WOOD AEROPLANE CONSTRUCTION

(*a*) Is part of a wing spar built from wood laminations glued together. (*b*) Shows a wing rib designed to withstand heavy stresses. This consists of a light framework covered with plywood. (*c*) Is a light type of wing nose rib. In (*d*) is a fuselage ring for a position near the tail unit.

under pressure for the twelve to twenty-four hours necessary for drying. Special glue is used, and this is usually reinforced by brads. The plywood side covering is also made from several pieces scarf-jointed together.

Fuselage Formers

The rings or formers for the fuselage are very similar in appearance to the metal type, except that the flanges are absent. They are made from plywood and have the usual lightening holes, and are also notched to receive the longerons. This work is done on routing and spindling machines identical with those described earlier. The assembly follows on generally similar lines to that for metal planes, except that glueing and

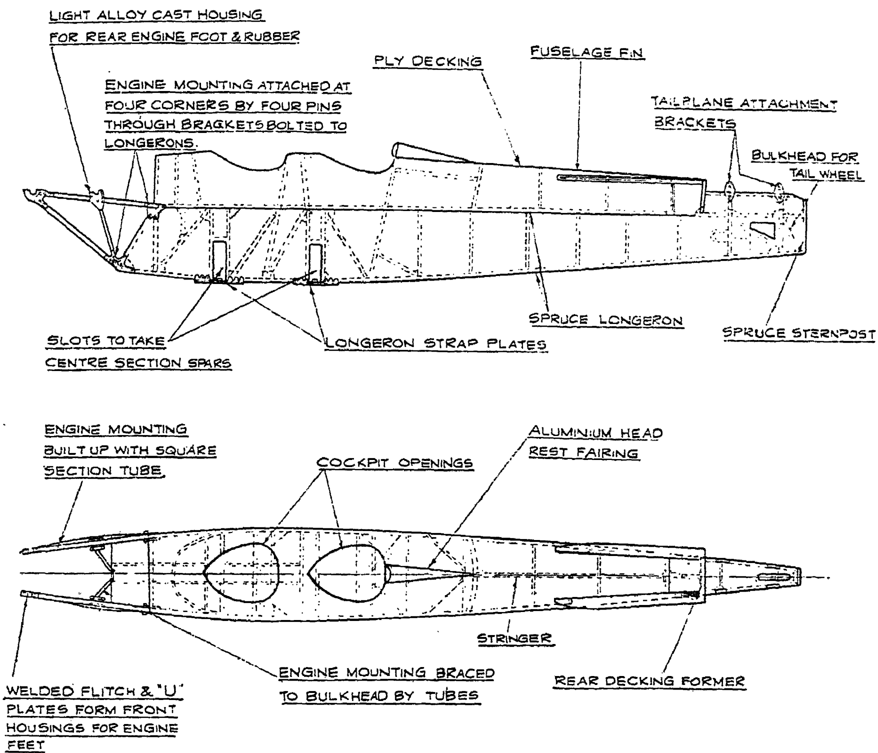


Fig. 71.—A TYPICAL WOODEN FUSELAGE—THE MILES MAGISTER TRAINER

bradding replaces riveting and drilling. Extra strength is provided in certain places by metal fittings and small wooden blocks. Parts which are notched to receive another part, as in the case of a longeron passing through the outer edge of fuselage former, are made oversize and a perfect fit is obtained by driving in two wooden wedges from opposite sides.

Plywood Skin

The skin consists of plywood, varying in thickness between $1\frac{1}{2}$ mm. and $2\frac{1}{2}$ mm., according to the position in which it is used. This is cut into panels or pieces of the correct size and shape which, if necessary, are bent to suit their future position, as in the case of the wing nose portion. Some of the woods are placed in a metal cabinet and subjected to the effects of steam under pressure for $\frac{1}{4}$–$\frac{1}{2}$ hour, this making bending more easy. It is then placed around a wooden former and tacked in position until dry. However, steam bending cannot be applied to all woods.

Fabric Covering

Fabric for wing covering is a plain woven flax material with a strength per inch in either direction of 90 lb. A number of pieces are cut simultaneously from a pattern, and several are stitched together so that they will cover the entire wing, top and bottom. This is wrapped around the wing so that the two edges join near the under surface of the trailing edge, the various joints being made with a special stitch. Reinforcing strips and patches are added wherever required, and the whole work calls for highly skilled attention.

After assembly the fabric is treated with dope in a separate department set aside for this work, the temperature being kept at a constant temperature of 65° F. A first application of a dope with sun-resisting properties is made with stiff brush, and certain patches are added. This is followed by another similar coat of dope. Two or more coats of a pigment dope are sprayed after this, each being allowed to dry before the next is applied. The final stage, after the addition of identification and other markings, is the application of a coat of transparent dope and then varnish.

Chapter VI

AERO ENGINES

THE majority of the components for an aero engine are produced by ordinary machine-shop methods. Special-purpose machines have been designed to enable some parts to be manufactured more quickly, but, in general, operations and plant differ very little from those used for ordinary good-class engineering work. The most important feature is that a very high degree of accuracy is required, this necessitating the employment of the best plant obtainable. Another feature is that, in order to accurately check the dimensions of the parts, much more elaborate gauging and inspection methods are required.

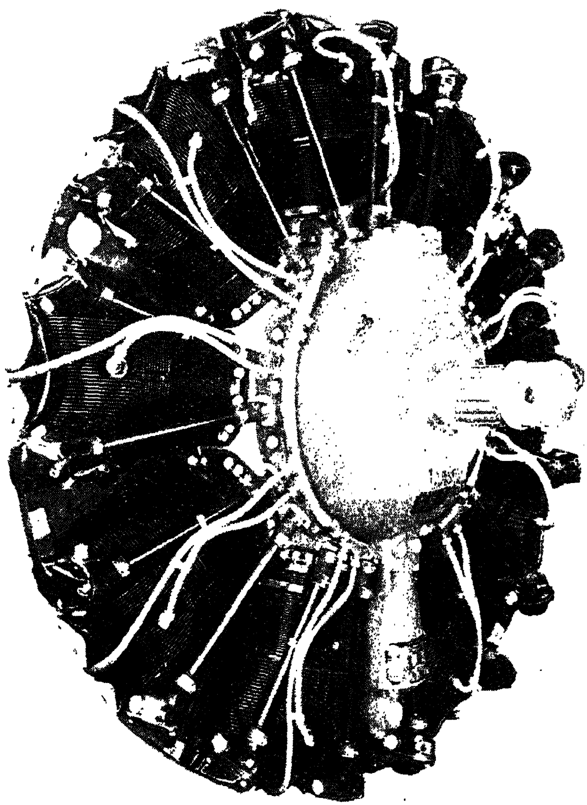


Fig. 72.—THE 1,200-H.P. WRIGHT G-200 CYCLONE RADIAL AERO ENGINE

This illustrates the complicated nature of the modern engine. (*Curtiss Wright Corp.*)

Automatic Milling

For many machining operations use is made of the well-known Keller automatic miller. This is a special type of machine employing "end milling" cutters held in a horizontal position. Above this is a tracer or finger which presses against a wooden or plaster model and, by means of electro-magnetic relays, causes the cutter to reproduce a shape identical to that of the model.

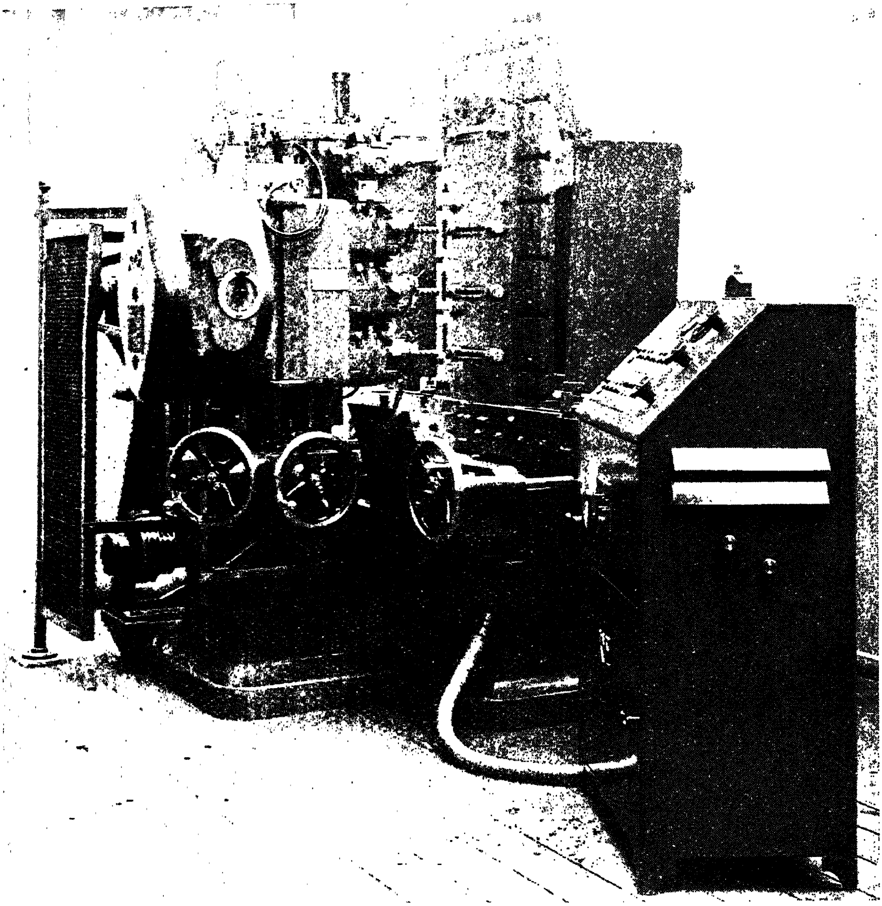


Fig. 73.—Simultaneously machining the contour of three connecting rods on a Keller automatic milling machine. (*Alfred Herbert Ltd.*)

Crankcase

An example of this can be seen in Fig. 74, which shows the milling of a crankcase for a radial aero engine. To ensure that the finished crankcase will be free from defects or weak spots, it is made from a solid forged billet of light alloy, considerably larger than the final article. This is bored and machined to the shape of cylinder, sufficient metal being left for subsequent finishing operations. The cylinder is then placed on a horizontal boring machine, where the holes are cut out to approximate size by a trepanning operation.

These " roughing " stages are followed by heat-treatment, which gives the necessary strength and other qualities to the metal, and also enables

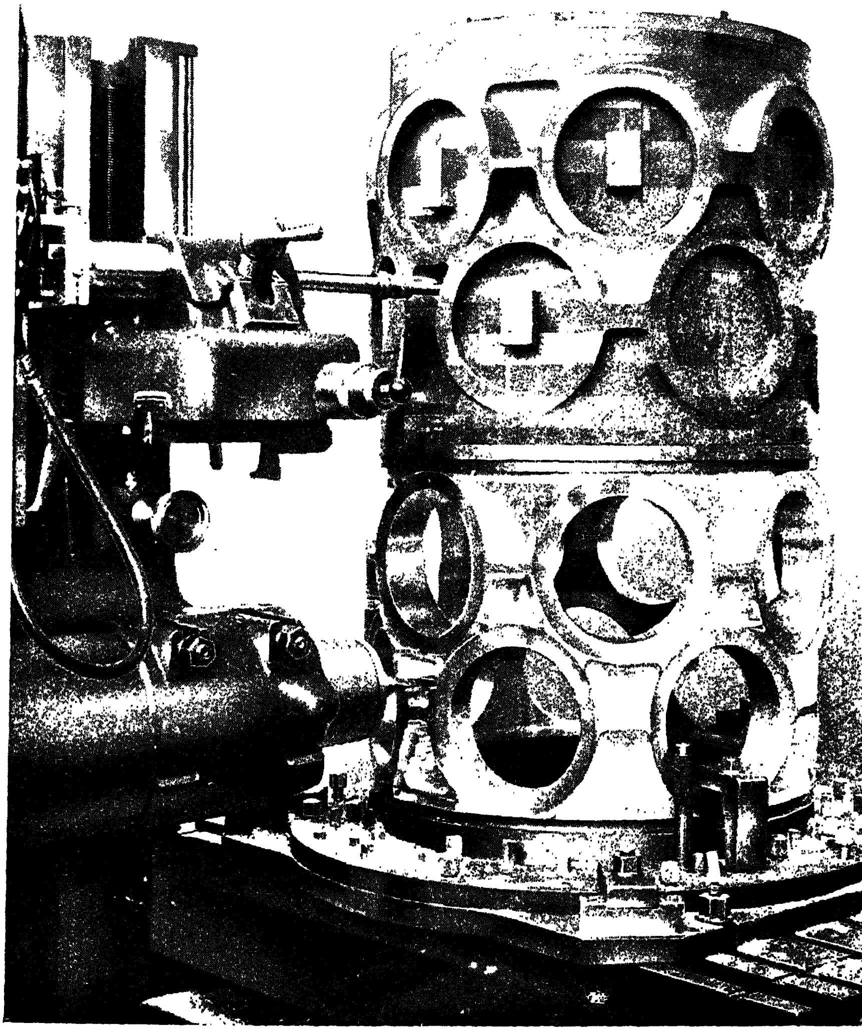


Fig. 74.—Removing surplus metal from the wall of a crankcase

This operation is done on a Keller automatic milling machine, using a wooden model as a guide. (*Alfred Herbert Ltd.*)

a much better surface finish to be obtained during the final operations. Again the rough crankcase is placed in a lathe or vertical boring machine, where the interior and top and bottom faces are turned to final size. Once more the work is sent to a Kearns or other similar type of horizontal borer, where the holes are machined to their final size. At the same setting the flat face surrounding the hole is machined.

A very high degree of accuracy is required regarding the spacing of the holes, and to ensure this the crankcase is fastened to a rotary fixture similar to that in Fig. 74. This consists essentially of a sturdy disc which can revolve on top of a base plate. Clamps are provided on the base to lock the disc in any position, and clamps are also fitted to the disc to secure the crankcase. Thus, if the base clamps are loosened the work and disc can be freely revolved by hand.

Drilled in the base, in a circular fashion, are a number of equally spaced holes corresponding to the bores in the crankcase. One hole, on the same pitch circle, is drilled through the disc. By removing and inserting an accurately ground pin through the holes, the work can be quickly indexed to each new position.

For the sake of lightness every ounce of unnecessary metal is removed from the crankcase, and the illustration shows the milling of the wall between the bores. The material is cut away until the wall is very thin, a boss being left around each bore. Stiffening ribs are also left between the bosses to provide extra strength.

All of this operation is performed automatically, using a wooden model as a guide. After completion of each section the work is indexed to the next position to present a fresh part of the crankcase to the cutter. When the crankcase is first produced as a billet, it is so heavy that two men are necessary to lift it on to the borer or lathe. When completely machined it can be lifted by one finger.

Connecting Rods

Another production job sometimes carried out on a Keller automatic milling machine is shown in Fig. 73. Here, with the aid of a multi-spindle machine, three connecting rods are being milled simultaneously. At the top is a model consisting of a finished component, whilst bolted directly underneath are three stampings. Special end-mills, cutting only on the sides, are held in the spindles and the machine is set so that they automatically traverse completely around the outside contour, thus milling the rods to the same dimensions as the model. Once the machine is set up the operator is free to attend to other work.

Forging

A considerable number of aero-engine parts are produced by the drop-stamping process (Fig. 24). Apart from quick and accurate production, components made by this process are free from internal defects (air-holes, slag, etc.), and have a much stronger structure than those produced by casting and other methods. This latter feature, particularly, is of more importance in the aircraft industry than in any other. Airscrew blades, crankcases, brackets, and numerous small fittings are stamped from light alloys, as well as engine parts from heavier metals.

Chapter VII

AIRSCREWS

THERE are two main types of airscrew (i.e. wooden and metal), both of which are available in fixed- and variable-pitch styles. Wood airscrews are still widely used and, due to recent improvements, are in some cases replacing the metal type. Mahogany and spruce are the two woods mainly used, the latter being particularly suitable for variable-pitch blades.

The wood is first sawn into boards and then placed for several days in a specially constructed kiln, where the amount of moisture in the wood is reduced to a certain standard figure. This is done by carefully controlled drying apparatus and steam jets which keep constant the humidity of the interior of the kiln. The amount of moisture in the wood is one of the most important factors in the manufacture of this type of airscrew, and the humidity of all the workshops is kept constant throughout the year to ensure that, after kiln treatment, the moisture content of the wood is not altered.

After this the boards are planed and cut to a standard thickness and length, and then weighed. In the case of single blades for v.p. airscrews the boards are made up into a block similar to that in Fig. 76. These blocks are practically all identical in weight to within a few ounces, due to careful grading and arrangement of the under-and-over-weight

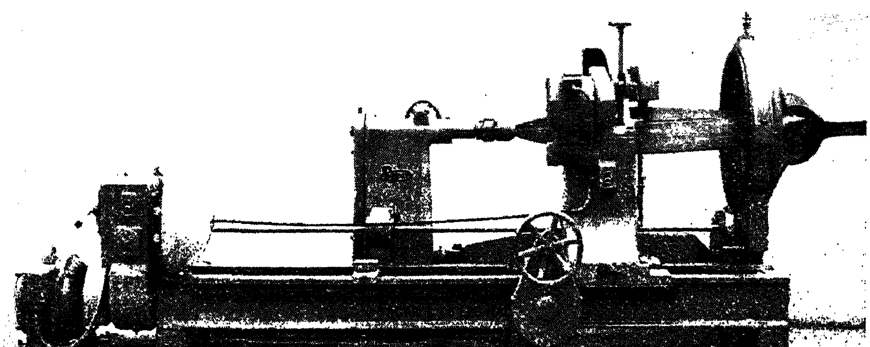


Fig. 75.—AN AUTOMATIC PROFILING MACHINE FOR SHAPING WOODEN AIRSCREWS

The metal "master blade" can be seen at the bottom. This view has been taken from the rear of the machine, and the blade being shaped is of the fixed pitch type. (*J. Sagar & Co. Ltd.*)

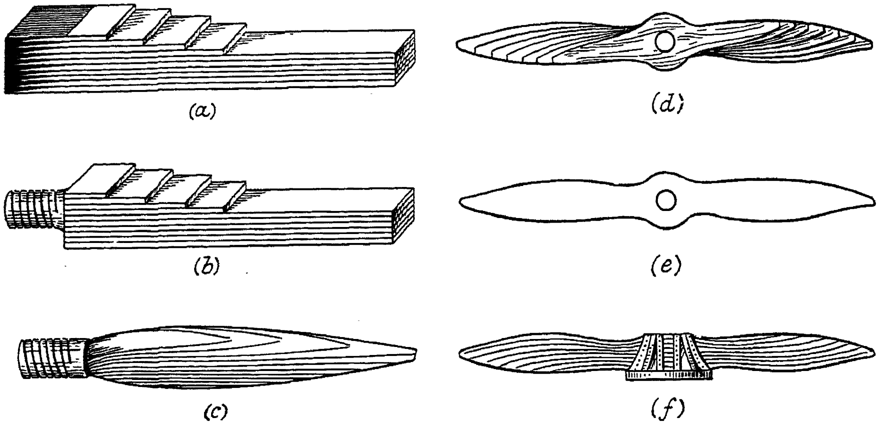


Fig. 76.—STAGES IN THE MANUFACTURE OF WOODEN AIRSCREWS

(*a*) A block composed of boards glued together. To the end of each is fastened a length of hard wood.
(*b*) The hardwood root is turned and screw-cut to receive a steel sleeve.
(*c*) The block is then shaped in an automatic profiling machine.
(*d*) Arrangement of the roughly shaped boards for a fixed pitch airscrew prior to gluing.
(*e*) The airscrew after shaping.
(*f*) Ribs for the cowl are attached by glue and screws before addition of the plywood cover.

boards. Constant-pitch blades are made into blocks by a slightly different method. The boards are roughly sawn to shape, provided with a hole through the centre, and balanced while loose. After grading the boards to obtain as accurate balance as possible, they are arranged to form a block (*D*), approximately similar to the required airscrew.

The next stage consists of gluing the boards together with a strong casein glue, steel screw-cramps being used to hold them in position. They remain here for at least twenty-four hours, after which they pass through a drying kiln to remove excess moisture due to the glue. Before reaching this stage, each board to be used for variable-pitch blades is joined to a piece of very hard wood, made by compressing layers of thin wood coated with a synthetic resin. This compressed wood forms the root end of the blade, and is so hard that it can only be cut with metal-working machines.

Shaping

After glueing, the blocks are placed in an automatic profiling machine (Fig. 75), where they are shaped to the approximate contour and size of the finished blade. Below the block is a metal " master blade " revolving at the same speed as the block. Pressing lightly on this is a wheel controlling the movement of a large milling cutter above the blade. Thus,

as the wheel is made to rise and fall by the master blade an identical movement is given to the cutter. Consequently, as the machine feeds along the bed the block is shaped to the same contours as the master blade.

The blade is brought to its final dimensions by the use of spokeshaves and scrapers, sheet-metal templates being used to check each few inches of the profile. After practically every stage the blades are carefully balanced against master-weights to ensure that each one, when completed, will be identical with those previously made. A plywood spinner is glued and screwed to the boss of the fixed-pitch blades, after which they are sprayed with a cellulose finish, and then dried.

Variable Pitch Hubs

The variable pitch blades, before passing to the automatic shaping machine, are placed in a lathe so that the hardwood root can be turned and screw-cut. This is done to allow the fitting of a steel adaptor sleeve which screws into the variable pitch hub of the aeroplane. After the sleeve is screwed to the blade-root special cement is forced into the threads to prevent it from working loose.

Surface Finish

All v.p. blades, and also many of the fixed-pitch type, are given a special finish which provides a surface as hard as that of metal blades. This treatment, known as the Schwarz patent process, consists of first covering the wood with a layer of fabric and then tacking a sheath of thin brass to the leading edge. The whole blade is then wrapped in a sheet of plastic material resembling green celluloid.

By a special process the plastic is forced through the fabric into the pores of the wood to form a very hard covering when set. The brass protects the leading edge during rotation in flight. A final hand-scraping operation is given to smooth the surface, after which the blade is spray-painted with a special cellulose finish.

Metal Airscrews

Metal airscrew blades are made by either a stamping or pressing process. First, the shape of the blade is cut into two steel blocks, half in each. Thus, when these two blocks or dies are placed together there is a space between them identical to the required blade. If the blades are to be produced by stamping the dies are fastened in a large drop-stamp where, by allowing one half to drop repeatedly on a billet of hot aluminium placed on the other, the metal is stamped to shape.

Pressing is carried out in a somewhat similar manner, except that the dies are fastened to the platen of a large hydraulic press and that the hot metal is squeezed to shape instead of hammered. This operation is followed by heat treatment to give strength to the metal, after which the blade is ready for machining to final size. Automatic milling machines

are used for this work, these copying from a master blade on a somewhat similar principle to that in Fig. 75.

Conclusion

From the foregoing pages the reader may feel tempted to think that the manufacture of aircraft has reached a final stage of perfection. The use of light metal pressings and stampings on an almost mass production basis, together with unit construction and jig-built parts, certainly have helped towards this goal. However, experiments are being made, notably in America, which may lead to an entirely new method of airframe manufacture.

It is claimed that a complete fuselage has already been moulded in a single piece from plastic materials. In its most crude form this means that it may become possible to merely pour a liquid plastic into a mould and, when set, take out a complete fuselage. A number of small parts, such as wing tips, landing lights, and windows, are at present made in this country from plastic materials, but it will be appreciated that these are not very highly stressed during flight.

Although it is quite probable that considerably more use may be made in the future of plastic materials, their application for highly stressed parts such as wings, tail units, and fuselages is very doubtful, unless new and stronger materials, and new moulding methods, are developed. The most promising development, about which very few details are yet available, consists of the use of plywood impregnated with a liquid plastic. This is formed to shape on a special press fitted with heated tools, and sets with a hard surface.

Chapter VIII

NOTES ON THE PRODUCTION OF A SLEEVE-VALVE AERO ENGINE

A SLEEVE-VALVE engine has a number of technical and constructional advantages over the poppet-valve type. These make production a simpler matter, resulting in increased output.

All the major parts are relatively simple and can be produced accurately and quickly with automatic or semi-automatic machine tools. It will be noted that the valve mechanism is fundamentally simple and is suited particularly to high-speed production, as there are no small highly stressed parts. Further, as the engine type is developed for larger sizes there would be no excessive increase in the cost of production.

Nearly all the machining of the parts comprising the cylinder assembly can be dealt with by turning, grinding, boring, and drilling, important considerations which reduce the number of special purpose machines to a minimum.

Sleeve Valve

The sleeve valve is made from an alloy steel specially chosen so that its coefficient of expansion is not greatly different from that of the light alloy barrel, as it is essential that correct working clearances are maintained in order that the system shall be gas-tight and at the same time be efficiently lubricated.

In the poppet valve engine the bore of the cylinder always shows greatest wear around the top piston ring, and the wear decreases along the length of the piston travel, but such local wear does not occur in the sleeve valve type. The combined rotary and reciprocating motion of the sleeve is good for spreading the oil evenly, and it has been found from experience that the wear is almost negligible.

For the purpose of manufacture the sleeve may be considered as a tube, and it can be made by extrusion, or spinning, rather similar to the centrifugal casting of iron pipes; this method gives fairly rapid cooling, and any impurities tend to be centrifuged to the outer surface.

The rotary and reciprocating motion of the sleeve is imparted by the sleeve drive cranks operating through the ball and socket unit attached to the skirt of the sleeve, and it will be realised that there is a considerable stress to be handled at this point. Further, the sleeve is comparatively thin and must withstand the explosion pressure without bulging into the ports of the barrel, therefore the sleeve, besides having the

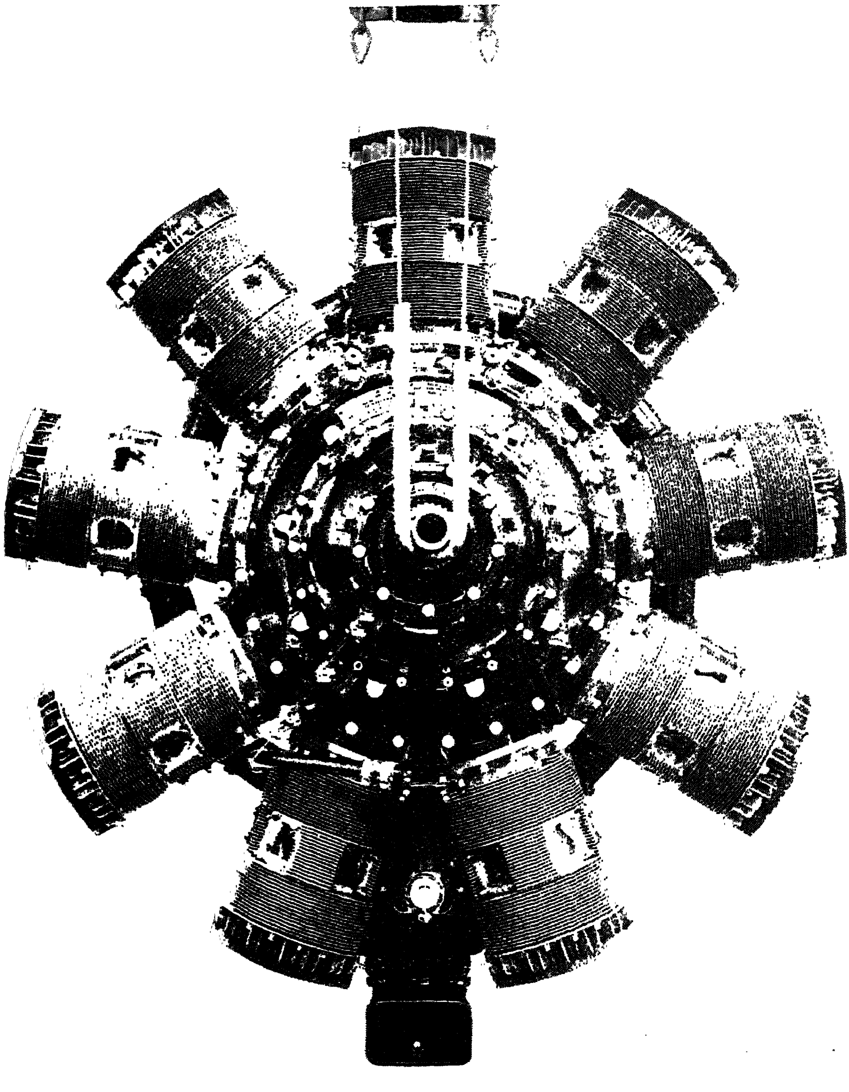


Fig. 77.—A MODERN SLEEVE-VALVE AERO ENGINE (FRONT)
This is the "Perseus" engine designed and manufactured by the Bristol Aeroplane Co. Ltd.

necessary strength properties, must be made with careful attention to grain flow, especially at the skirt carrying the ball and socket joint.

The machining of the sleeve valve is similar to that of a cylinder liner; it is turned and bored, the ports are cut and both surfaces are carefully ground. Fig. 77 shows the machining of the ports in the sleeves and barrels.

The sleeve is subjected to many inspections during its course of manufacture, including X-ray ; the internal and external dimensions of the sleeve are finally checked on a " Solex " indicator.

The boring and drilling of the sleeves and crankcases are shown in Fig. 79.

Crankcase

The crankcase, consisting of front and rear half, is made from an aluminium forging. The front half which carries the train of gears and sleeve driving cranks has the requisite number of radially disposed holes, and these are drilled in a multi-spindle machine. The cylinder barrel aperture is shaped to provide suitable clearance for the ball and socket joint.

Junkhead or Cylinder Head

The junkhead shown in Fig. 80 is made from an aluminium die casting.

The fins are cleaned up to remove any roughness remaining after casting, and all radii are blended with care since it is important that there is the minimum of skin friction to affect the flow of cooling air in and out of the head.

Holes are drilled for the studs and sparking plugs, and the part which fits inside the barrel to seal the sleeve is turned and the grooves cut for the piston rings.

Cylinder Barrels

The barrels are made from aluminium forgings and have close pitched fins machined all over except where the inlet and exhaust ports are situated. At these parts the barrel is turned down to the fin root diameter. The barrel is bored, and the ports are cut on an automatic machine. Other operations deal with drilling, (*a*) the lower flange for the holding down studs, (*b*) the holes at the top of the barrel to take the studs for securing the junkhead, and (*c*) the stud holes at the ports for holding the induction manifold and the exhaust outlet pipe.

The finishing of the ports by scruffing and polishing is important, so that the best flow of gas is ensured according to the movement of the sleeve.

Sleeve-drive Cranks

These right-angle cranks are machined from an alloy steel forging carefully made to ensure correct grain flow. The cranks are turned and ground in the usual way, the front pin of the crank is splined to engage with the appropriate driving pinion, and the rear pin is lapped and fits into the bronze ball of the socket joint at the bottom of the sleeve.

Piston

This is a light alloy drop forging ; it has four piston ring grooves and is diamond turned in the usual way.

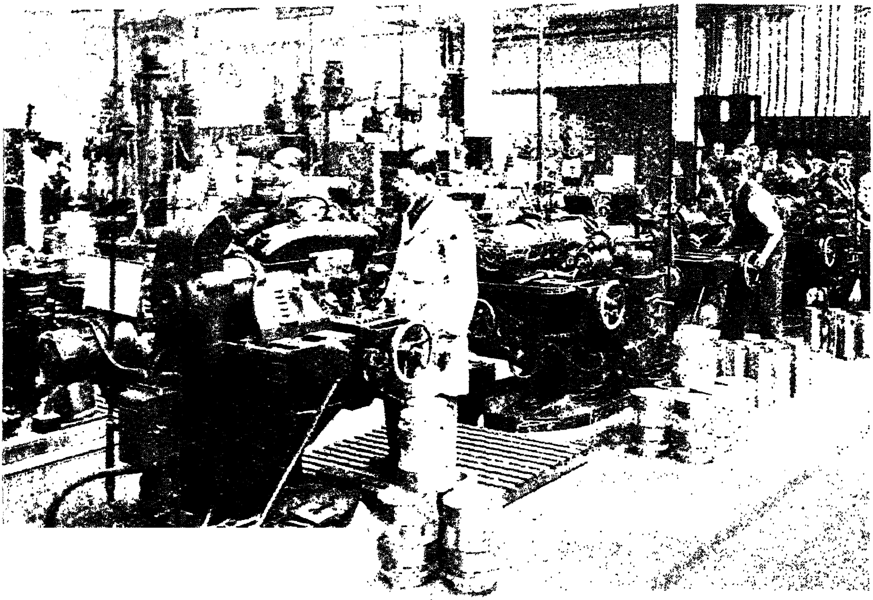


Fig. 78.—Cutting the ports in sleeves and barrels

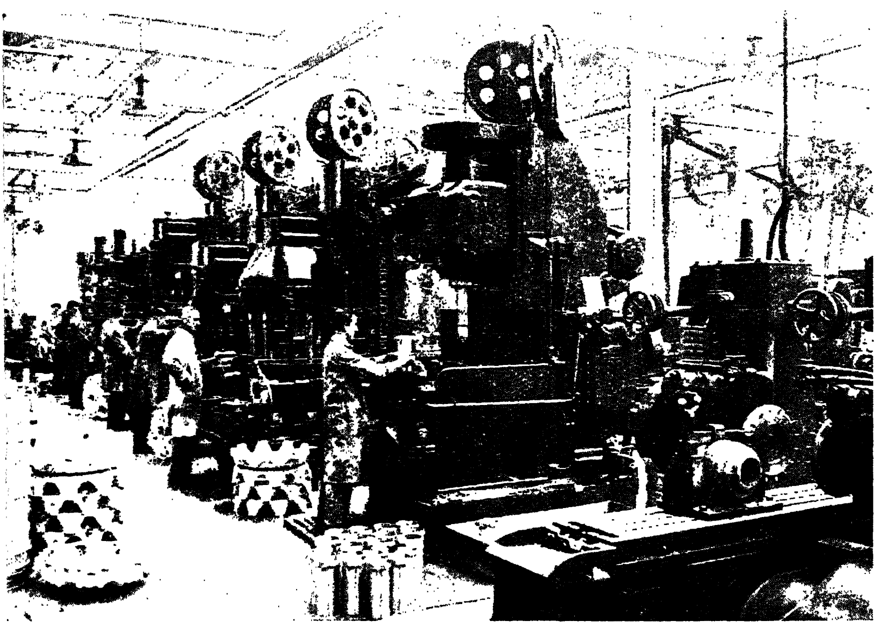


Fig. 79.—Drilling and boring crankcases and sleeves
A barrel forging can be seen in the right-hand machine.

Fitting and Sub-assembly. Crankshaft and Connecting Rods

With the exception of the cylinder assembly and the train of gears in the front half crankcase for driving the sleeve drive cranks, the unit assembly is generally similar to that of a poppet valve type.

The front and rear halves of the built-up crankshaft are assembled separately, with the main bearing inner race, crankshaft oil sleeve, etc. The tailshaft is fitted to the rear half crankshaft.

The connecting rod assembly can then be assembled on to the crank-pin, care being taken to ensure absolute cleanliness and plenty of oil. The rear half crankshaft is then fitted to the front half by expanding the maneton bore, care being taken to see that the crankpin and maneton bore are quite clean and free from oil or grease. When completely assembled the crankshaft and connecting rod assembly is subject to an oil pressure test to ensure that the oil plugs are tight, and that oil exudes where necessary for lubricating the floating bush, articulated rod pins, etc.

Reduction-gear Unit

The reduction gear unit, consisting of the airscrew shaft, bevel pinions, bevel gears and bearings, and front thrust bearings, is then assembled ready for building into the engine.

Supercharger Unit

This unit includes the assembly of the spring drive gear, intermediate gear and pinions which is built in to the blower casing, the whole unit being completed by the fitting of the impeller. The volute casing and cover is then assembled to the blower casing.

Crankcase

The two half crankcases are studded, and fitted with bearing housings, the front half being fitted with the bearings carrying the train of gears and the sleeve drive crankpins. The gears and cranks are finally fitted and timed, so that the cranks are in the correct position for receiving the ball and socket joint at the lower end of the sleeves.

Rear Cover

The rear cover with its drives and accessories is then built up and tested.

Erection of a Sleeve-valve Engine. Crankcase

The rear half crankcase is fitted to the engine building stand, then the crankshaft and connecting rod assembly is suspended in position, the bearing rollers are assembled, then fitted to the rear half crankcase. The front half crankcase is assembled on to the crankcase bolts with the cylinder half apertures correctly aligned with those of the rear half crankcase, care being taken that the front and rear oil sump joint faces

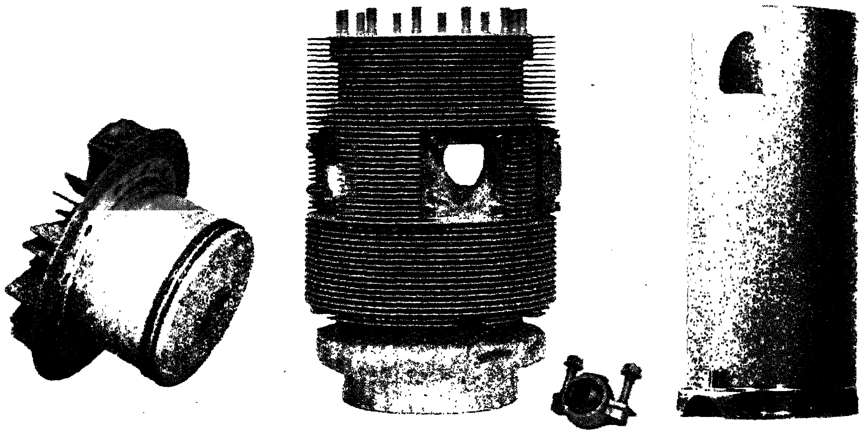


Fig. 80.—Showing sleeve, barrel, and junkhead

are in line, at the same time seeing that any necessary adjustment is made to the alignment of the assembly rollers on the inner race in the front half crankcase. The crankcase bolts are then tightened.

Pistons, Sleeves, and Cylinders

Number six cylinder should be assembled first.

1. Assemble the piston to the connecting rod and press in the gudgeon pin. Fit the steel rings and circlips.

2. Turn the crankshaft to bring both the sleeve driving crank and piston to T.D.C. position.

3. Evenly space the gas and scraper ring gaps.

4. All working surfaces must be smeared with clean mineral oil when assembling.

5. Assemble the sleeve ball and housing on the crank end. Fit the sleeve guides to the ball housing studs and assemble the sleeve, using the piston ring clip to facilitate entry of the piston rings. Thread on the ball housing nuts and screw home. Remove the guides and tighten the nuts, using the special spanner provided. Finally lift the locking plate with the tool provided and rotate to engage with the serrated flange of each nut.

6. Immediately before fitting the cylinder, fit the rubber sealing ring previously dipped in engine oil. Ensure that the ring is not twisted when finally positioned on the cylinder spigot. Slide the cylinder over the sleeve, noting that the induction pipe sleeves, rubber ring, and ring holder are in position on the induction pipe ; fit the plain and spring washers and tighten the cylinder securing nuts.

7. Assemble the cylinder head, using the special cylinder head ring band to facilitate entry of the cylinder head rings into the sleeve bore. Fit the plain spring washers and tighten the securing nuts.

8. Secure the induction pipe ring holder with the bolts and spring washered nuts. Fit the H.T. wires and clips.

9. The sump is now fitted.

10. Assemble the inter-cylinder baffles, noting that the distance pieces are in position on the cylinder head studs prior to tightening the baffle bracket securing nuts. Finally connect the exhaust pipes.

The other sub-assemblies, similar to the poppet-valve type, including front cover, reduction gear unit, supercharger unit, carburetter, rear cover unit and ignition system, are built on to the crankcase following the usual practice, and the necessary check tests are made.

Engine Test

After the engine has passed inspection following erection, it is passed to the running-in shop, where it is run for five hours on spindle oil, which is supplied very copiously in order that any stray dirt may be washed away.

An electric motor rotates the engine at about 500 r.p.m., and in place of sparking plugs gauze-covered blanks are fitted.

After being run-in the engine is transferred to the dynamometer test stand, and the necessary pipe lines and controls are fitted.

The engine is first of all motored for about a quarter of an hour by an electric motor, and then allowed to run under its own power at low r.p.m. for some time while any necessary adjustments are made to the carburetter.

The engine is then put through the endurance test, and after the various readings and power checks have been passed it is returned to the shops, where it is stripped down for a careful inspection. Following this, the engine is re-erected and again sent to the test stand for the final test of power, slow-running, and acceleration. Having successfully passed the final test, the engine returns to the shops for an external inspection, and is then prepared for despatch.

If the engine is a new type or embodies some particular modifications, it might undergo a considerable amount of flight testing, but the normal production engine would be ready for installation in a production airframe.

Standardised Power Unit

The variety of power units and equipment has emphasised the necessity for standardising the installation of engines and their accessories, and in this respect considerable development has been carried out with the sleeve-valve engine, so that the unit may be established on a production basis.

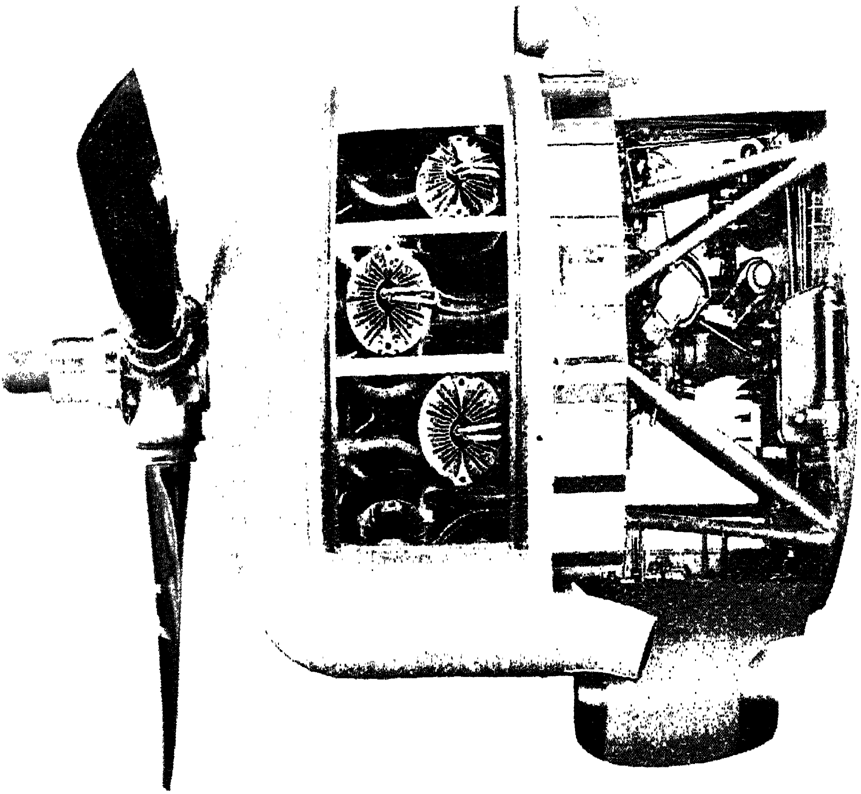


Fig. 81.—Hercules power unit installation

A typical power unit is shown in Fig. 81. It comprises a two-row sleeve-valve engine with airscrew, exhaust system, cowling and controllable cowl gills, accessories, and auxiliary drive gear-box mounted on the bulkhead. It will be seen that the engine unit is carried in a triangular tubular mounting for attaching to four standardised pick-up points in the front bay of an airframe.

The various electrical, mechanical, and hydraulic connections are grouped at the bulkhead so that interchangeability between aircraft may be obtained.

INDEX